Architects' and Engineers' Hand-Book of

Re-Inforced Concrete Constructions

BY

L. J. MENSCH, C. E.

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CHICAGO, ILL.

ARCHITECTS' AND ENGINEERS'
HAND-BOOK OF

RE-INFORCED CONCRETE CONSTRUCTIONS.

Giving in plain and simple language the leading principles and applications of this modern construction.

WITH NUMEROUS ILLUSTRATIONS AND TABLES.

BY

L. J. MENSCH,

CIVIL ENGINEER AND CONTRACTOR.

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GENERAL

C. F.

INTRODUCTION.

The information given in this Hand Book is drawn largely from the writer's own experience as Designer, Consulting Engineer and Contractor for re-inforced concrete constructions.

In the practice of his profession in various parts of the country, he has been brought in contact with architects, engineers, contractors and capitalists, interested in this new method of construction. These clients and others have from time to time propounded numerous pertinent and carefully considered questions, relating to the essential features of re-inforced concrete construction, especially as compared with other materials and forms of construction. These questions and the writer's answers were uniformly reduced to writing, classified and preserved and now form a portion of this Hand Book, together with other matter bearing directly on the subject.

The writer has aimed to treat the subject in plain, simple language, entirely free from higher mathematical calculations.

The mathematical side of this subject will be exhaustively treated in the more extensive treatise now under way by E. Lee Heidenreich, to be published by the *Cement and Engineering News*.

Re-inforced concrete is the ideal building material of the future and must in a great measure displace the older materials of construction upon its intrinsic merits.

Re-inforced concrete construction is at the present time little understood by our most competent engineers and architects, due simply to the absence of suitable literature in the English language on the subject.

If this Hand Book becomes the medium of conveying the desired information to the architects and engineers and thereby promoting the more general use of this new method of construction by the public, the writer's aim will have been accomplished.

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REINFORCED CONCRETE.

It can not be said that modern steel structures are perfection. Prominent engineers foretell great disasters in the near future on account of the insufficient protection of the steelwork in many of our modern office buildings. To-day railway and highway bridges of steel are considered temporary structures and require great expense for maintenance. Steel construction is expensive and not durable. Wood is cheaper, but less durable, and a good quality of timber is becoming more expensive from year to year. Owners, architects and engineers are asking themselves what to do. Shall they build at ruinous prices in steel, or shall they build a fire-trap or a temporary structure? Here reinforced concrete solves the problem.

WHAT IS CONCRETE AND WHAT IS REINFORCED CONCRETE?

Concrete is an artificial stone, produced by thorough mixture of cement, sand, crushed stone or gravel with water, placed into forms and tamped. The cement unites chemically with the water and binds the sand and crushed stone or gravel so firmly together that the crushing strength of concrete equals that of the most durable natural stone.

The use of concrete began with the dawn of civilization. We find concrete in the oldest buildings

of Mexico, in the Greek colonies in Italy and Sicily; the largest dome in existence, that of the Pantheon in Rome, 142 feet in diameter, is a solid mass of concrete, about 2,000 years old. In the Middle Ages we find concrete used for the walls of many castles and abbeys.

Concrete fell, eventually, into disuse, during the dark Ages, and was only revived by the discovery of Portland Cement in the early part of the last century, affording a much superior material than that used prior to this time.

The use of concrete was almost entirely confined to footings and walls on account of its low tensile strength, making it a very expensive material in all cases where crossbending stresses are to be overcome. This deficiency can, however, be remedied by imbedding steel rods in the concrete in proper sizes and positions, so that all tensile stresses from bending, change of temperature or initial set of concrete are taken care of.

This is known as Reinforced Concrete, Concrete-Steel, Ferro-Concrete or Armored Concrete.

The first reinforced concrete structure which came to public notice was exhibited at the World's Fair in Paris in 1855. It was a small rowboat built by a Mr. Lamont, of a shell of cement mortar 1 1-2 inches thick and reinforced by a wire netting. It is still in service in a pond in Miraval, France.

In 1867 Mr. Francois Monier obtained the first Letters Patent on reinforced concrete construction and subsequently built many water tanks, water mains, sewers and even houses of armored concrete. Large companies are now doing business in the Monier system

in all civilized countries. In 1877 we find Mr. Thaddeus Hyatt actively engaged in reinforced concrete construction in New York and London. He built vaultings, cement and steel side walk lights, and engaged also in the fireproofing business. He had a great many tests made on reinforced concrete beams by the well known Dr. David Kirkaldy of London, which first demonstrated to the scientific world the great economical advantages of this new construction.

During the last twenty years Mr. E. L. Ransome built in this country a number of important structures in reinforced concrete. The great impulse to concrete construction was given in 1892 when Mr. François Hennebique opened a consulting engineer's office in Paris, and, in conjunction with licensed contractors all over the world, designed and erected nearly ten thousand structures in Armored concrete, valued at nearly one hundred million dollars. The structures designed by him were a success from the very beginning, stood all the tests prescribed by building ordinances and specifications of engineers and architects, and soon by their great strength and durability and their low price found favor with municipal and state governments, who, after careful investigation, adopted them for work of the greatest importance.

We will now explain the various details of armored concrete construction classified as follows: Girders, floor slabs, roofs, columns, walls, retaining walls, tanks, stairs, etc.

THE ARMORED CONCRETE GIRDER.

Fig. 1 shows the elevation, Fig. 2 the section, Fig. 3 a perspective view of the girder. It consists essentially of a concrete rib reinforced by plain round steel rods, part of which are straight and part of which are bent into hog chain form, and a number of "U" bars or stirrups of hoop steel. In comparison with a steel girder (see Fig. 2) we see that the lower flange of the steel girder is replaced by the steel rods, the upper flange of the steel girder by the concrete floor and the web by the concrete rib and the "U" bars.

The reader will ask the reason for bending up the steel rods and for the "U" bars. Experience has demonstrated that concrete ribs, which are reinforced by a high percentage of steel, which is nearly always the case, the girders being made as small as possible to save head-room, weight and forms, do not show the first signs of failure in the center, but show it near the supports by diagonal cracks, produced by the combined shearing and tensile stresses which are maximum near the supports. The inclined portion of the bent rods take up part of the shear and the "U" bars, which are set close together near the supports, take up the tensile stresses which arise from the action of the remaining part of the shear.

A reinforced concrete girder is much safer with "U" bars than without them. Should the concrete ribs from any reason crack vertically or diagonally, it is clear

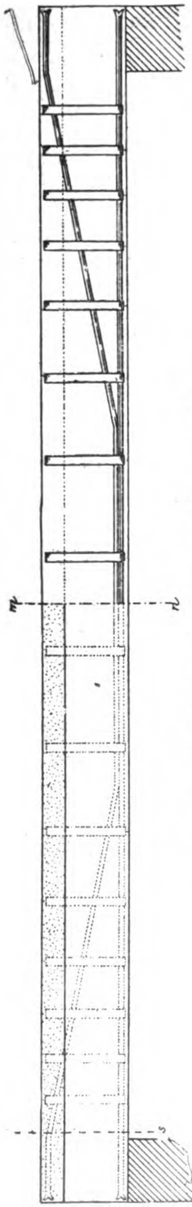


Fig. 1.—Elevation of Armored Concrete Girder.

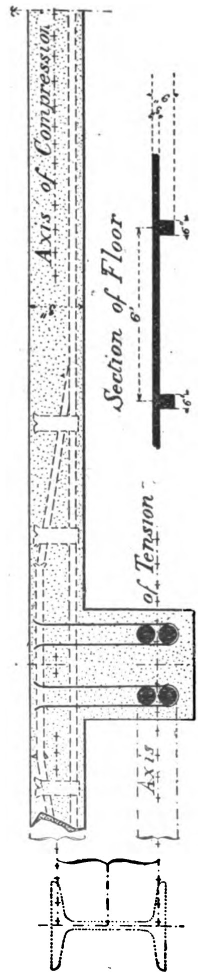


Fig. 2.—Section of Armored Concrete Girder.

that the steel rods would alone hold the girder together and that there would be a tendency to push the rods out of the concrete, which cannot happen where the "U" bars are used.

We have said that the concrete floor takes up the compression of a concrete-steel girder, and in most cases the section of the concrete floor suffices; in case

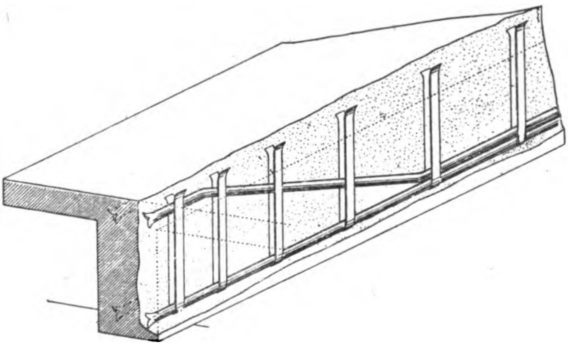


Fig. 3.—Perspective View of Armored Concrete Girder.

of heavy girders of small depth, however, also the top part of the concrete rib is to be reinforced by steel rods, which must take up the difference between the figured compression in the upper part of the girder and the compression, which it is safe to allow on the concrete floor.

In building construction girders are seldom freely supported at the ends. They are monolithically connected with other girders, they are continuous, and therefore much stronger than freely supported girders. The deflection of the girders is considerably reduced, as we know that continuous girders show deflections, which are one-half to one-fifth the deflection of freely supported girders.

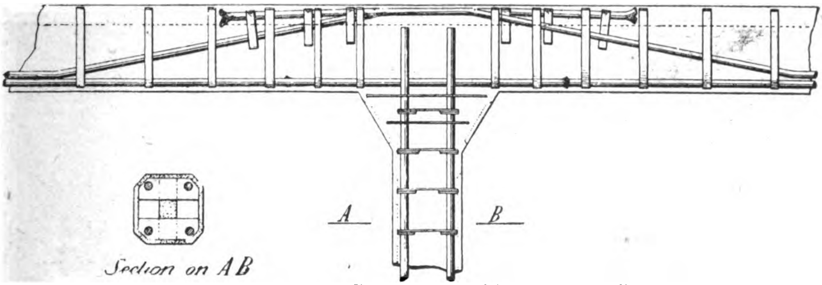


Fig. 4.—Connection of a Continuous Girder to a Column.

The economical depth of armored concrete girders about equals the depth of steel girders of the same carrying capacity and should not, as a general rule, be less than 1-20 of the span. The width of these girders is:

6 inches for girders corresponding to 12 inch I beams.
8 inches for girders corresponding to 12 inch to 18 inch I beams.
10 inches for girders corresponding to 20 inch to 24 inch I beams.
12 inches for girders corresponding to rivetted girders of 30 to 40 inches height.
Up to 24 inches for girders corresponding to very heavy box girders.

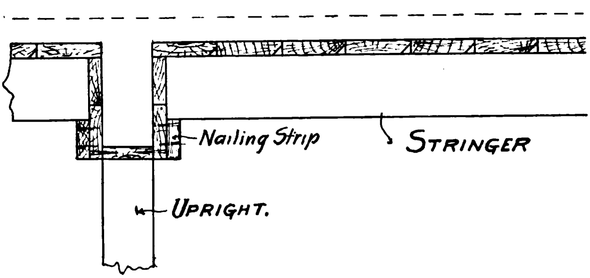


Fig. 5.—Forms for Girders and Floors.

Concrete girders are manufactured in wooden molds, called forms, at the site, in place, where they belong, as shown in Fig. 5. The mold for each beam consists of a 2 inch bottom plate, and two 2 inch side plates, screwed or clamped to the bottom piece. These molds should be supported every five feet by an upright, and the striking of the centering for the girders should not be commenced before three or four weeks after concreting.

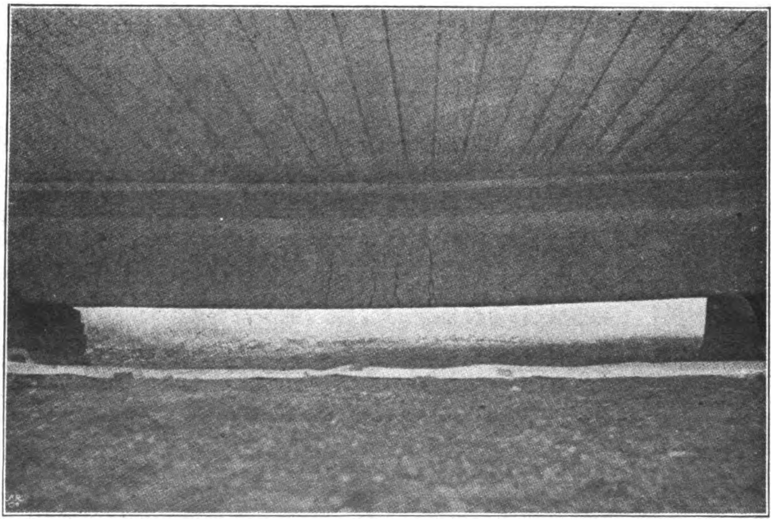


Fig. 6.—This Beam was designed for a super-imposed load of 4 tons, and was tested by a load of 34 tons. It cracked in the center and deflected considerably; nevertheless, it carried the load for 4 years without further sign of weakness.

Reinforced concrete girders can span any distance used in building construction, and carry any load up

to many hundred tons. In the larger spans the weight becomes excessive and we can lay down a limit for the span of these girders in buildings at perhaps 100 ft., for bridges perhaps 150 feet; arched ribs, however, can be built for much larger spans.

We see thus, that the science of reinforced concrete girders is well developed; all stresses as tension, compression, and shear, are properly cared for by the experienced designer, and the result is an indestructible girder construction, which under tests proves a strength beyond expectation. We cite the following tests made on girders designed in Armored Concrete which tests were made according to contracts when the buildings were partly or wholly completed, and which tests must convince any fair-minded person of the safety of this modern construction, which is destined in the near future, to be the only construction.

Mr. Frederick Baird, Architect, 218 American Trust Bldg., Cleveland, O., writes:

Mr. L. J. Mensch,

Monon Building, Chicago,

Dear Sir: Regarding the test made at the Salvation Army building, Dec. 16, 1902, I am pleased to give you the following data: The floor beams tested were 8 ins. x 16 ins., 7 ft.-0 o. c., with clear span of 23 ft. 6 ins. One end of same connects to a column, and the other to a girder 8 ins. x 16 ins. near the center of the same. The girders, floors, columns, footings, galleries and stairs were all constructed in armored concrete, to sustain a live load of 125 lbs. per sq. ft. floor loads. In the test, the above floor space over the girder 7 ft. x 23 ft. was loaded gradually to 600 lbs. per sq. ft., which was approximately 100,000

lbs. on the beam. The greatest deflection was about 3-8 in., and the final set was 1-8 in.

The beams and floors showed no signs of cracks or other defects, and the whole test was eminently satisfactory. The construction throughout and the materials used were of the best quality, and promise to be

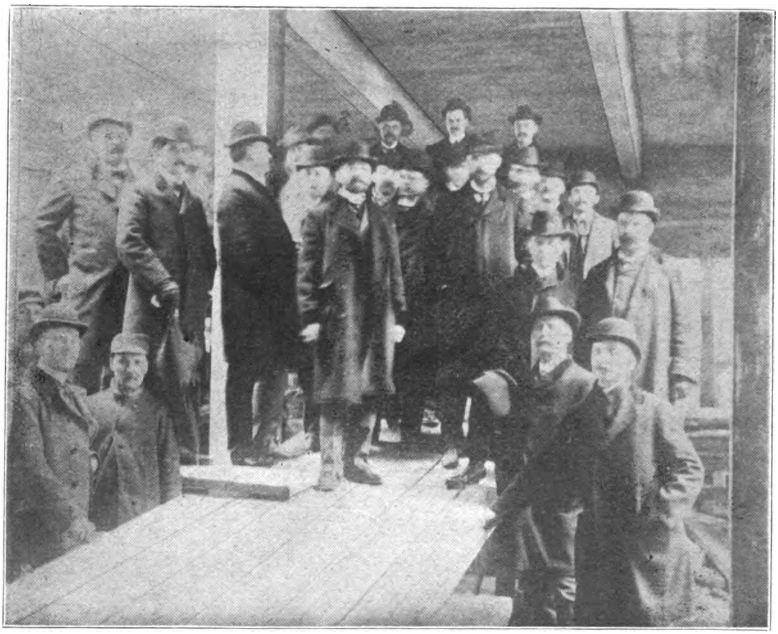


Fig. 7.—Test of Girder, Salvation Army Building, Cleveland, O.

as durable as anything yet obtainable or known to science—and also caused us a saving of 23 per cent over the cost in steel framing with tile floors.

Yours truly,

(Signed) FREDERICK BAIRD.

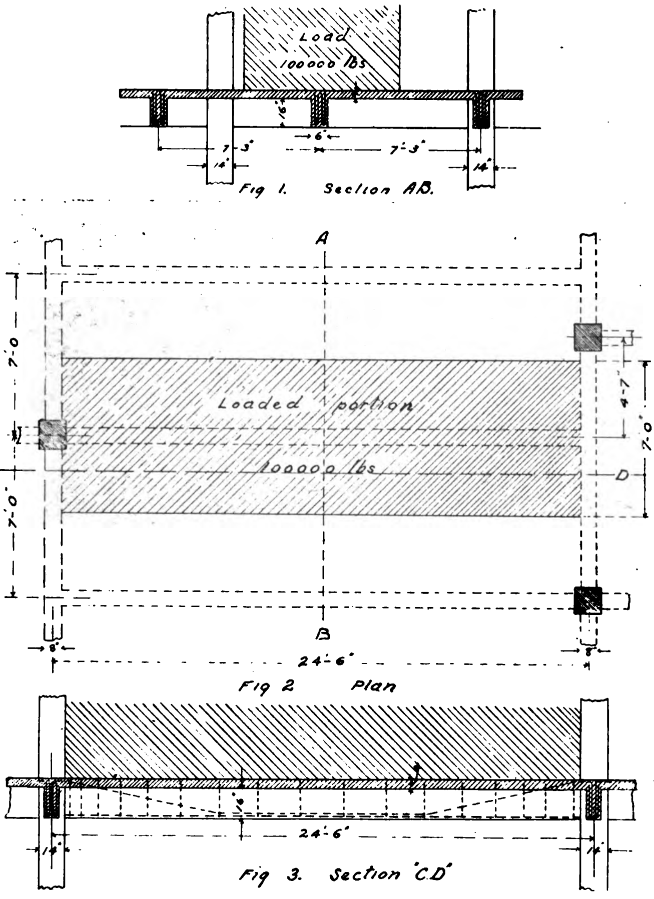


Fig. 8.—Diagram of Girder 24 feet, 6inches span, loaded with 100,000 pounds, Salvation Army Building, Cleveland.

Mr. F. B. Heathman, Architect, Dayton, O., writes:

MR. L. J. MENSCH,

Monon, Bldg., Chicago, Illinois.

DEAR SIR: In answer to your letter inquiring about the tests made on the concrete floors and girders at

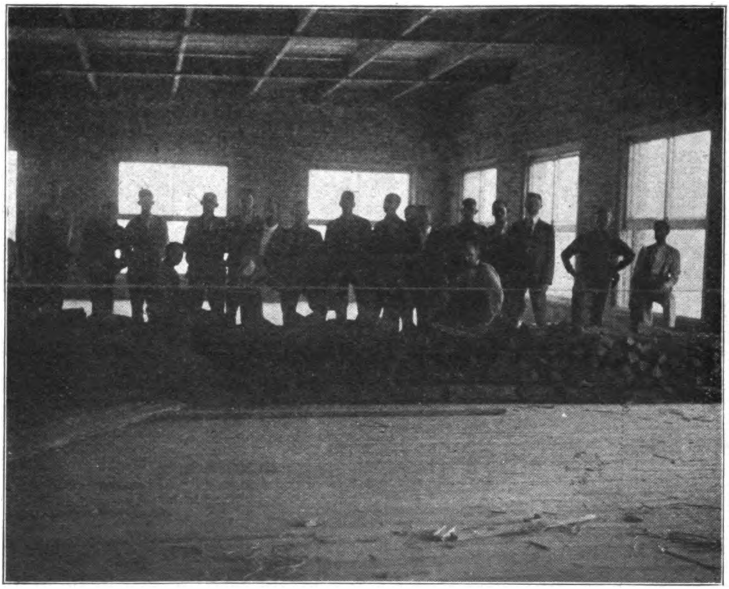


Fig. 9.—Test of Girder of 27 feet span at the Davis Sewing Machine Company's Office and Ware-house. Load, 124,000 pounds.

the Davis Sewing Machine Co., of this city, I am pleased to say that they were more than satisfactory, and that the company and all concerned are praising the work.

The long girders, 26 ft. span, were the only ones tested. The floor was weighted to 400 pounds per square foot, twice the load for which is was designed,

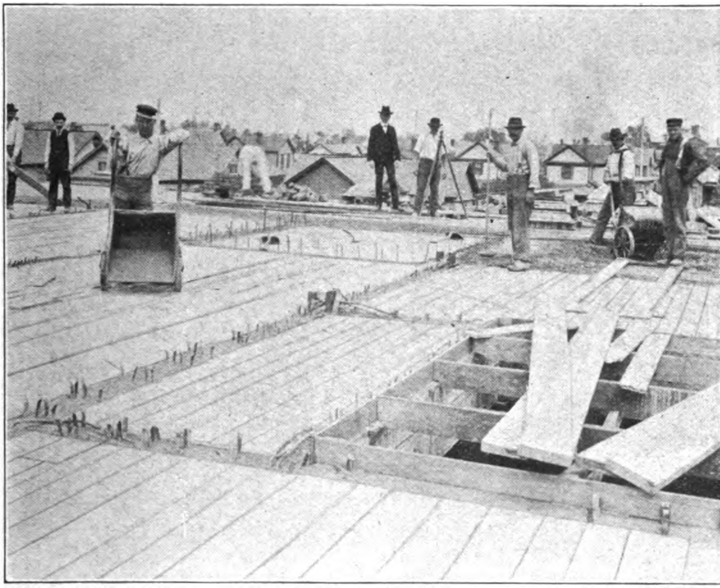


Fig. 10.—Concreting of Floors, Davis Sewing Machine Co.

making 124,800 pounds on one girder. The greatest deflection was found to be only one-tenth of an inch.

Very truly yours,

(Signed) F. B. HEATHMAN.

Mr. G. W. Drach, Architect, Cincinnati, O., writes:

MR. L. J. MENSCH,

Monon Building, Chicago,

MY DEAR MR. MENSCH: The test of the balcony at the College of Music was very satisfactory. The bal-

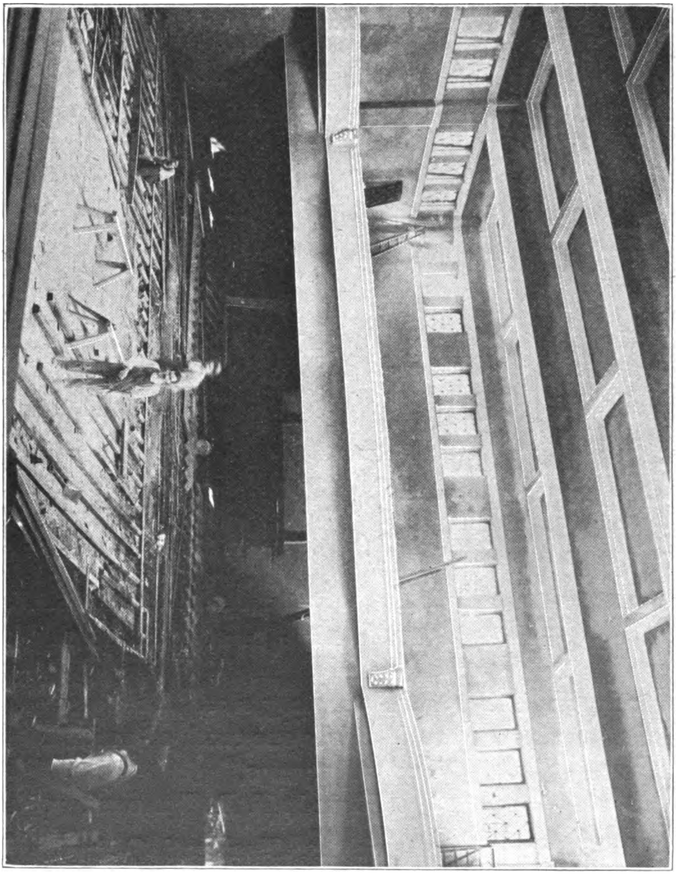


Fig. 12.—Roof and Balcony, College of Music, Cincinnati. 61 Foot Span.

cony, with girders of 61 foot span, was loaded in the in the center a little over 51,000 pounds. The deflection was 3-16 of an inch. We propose to allow the load to remain until to-morrow. The deflection has not in-

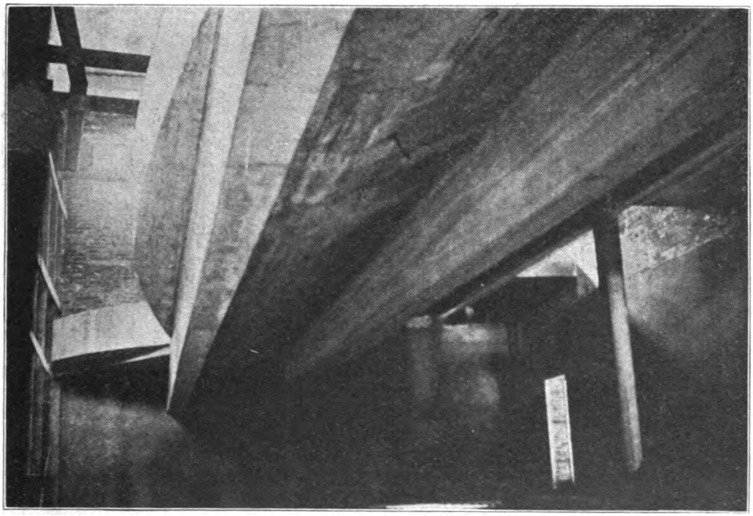


Fig. 11.—Balcony Girders of 61 feet span, College of Music. Cincinnati, O., One girder 2 feet 8 inches deep, one Girder 3 feet 2 inches deep.

creased any from 4 o'clock p. m. yesterday up to 9 o'clock this morning.

Yours very sincerely,

(Signed) GUSTAVE W. DRACH.

Mr. Paul S. Ward, Mech. Engineer for the J. H. Day Co., Harrison and Bogen Aves., Cincinnati writes:

MR. L. J. MENSCH,

Chicago, Ill.

DEAR SIR: Yours of September 3rd at hand asking us for report of test of concrete floor in our new foun-

dry building, and are sending you herewith a brief statement of the result of the test as made on the section of the building adjacent to the old shop.

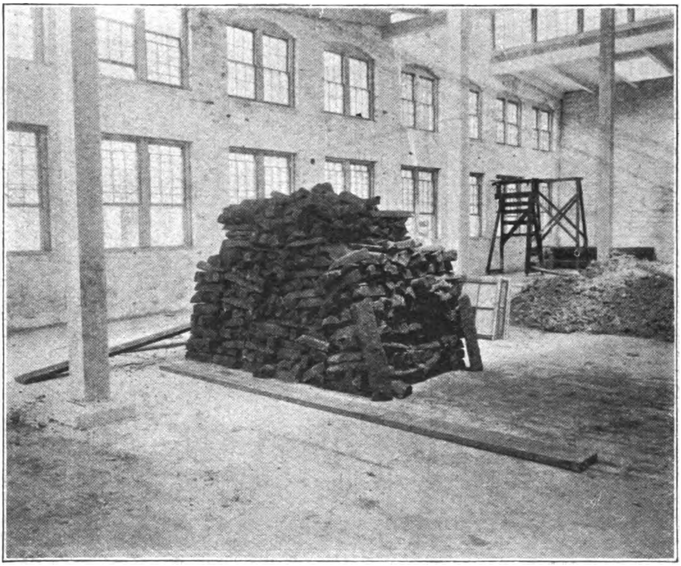


Fig. 13.—Test load of 77 000 pounds, J. H. Day & Co.'s Foundry, Cincinnati, O.

We first tested a floor beam in the construction, loaded it with a uniform distributed load over a surface of 10x20 feet. The beam being immediately under the longitudinal center line of this surface, and as the contract required this to sustain a load of 375 pounds per sq. ft. with a deflection not to exceed 1-800 of the length of the span, we distributed 77,000 pounds of pig iron as uniformly as practicable over the surface mentioned above. The beam showed a deflection of 1-16 of an inch when 1-3 of the load had been

placed, but this only increased to 2.4. MM, or about 3-32 of an inch with the full load of 77,000 pounds with no evidence of any weakness, no cracks developing, or none showing that might have existed before the load was placed.

We next loaded a girder with as nearly a concen trated load as was possible, if you will remember the

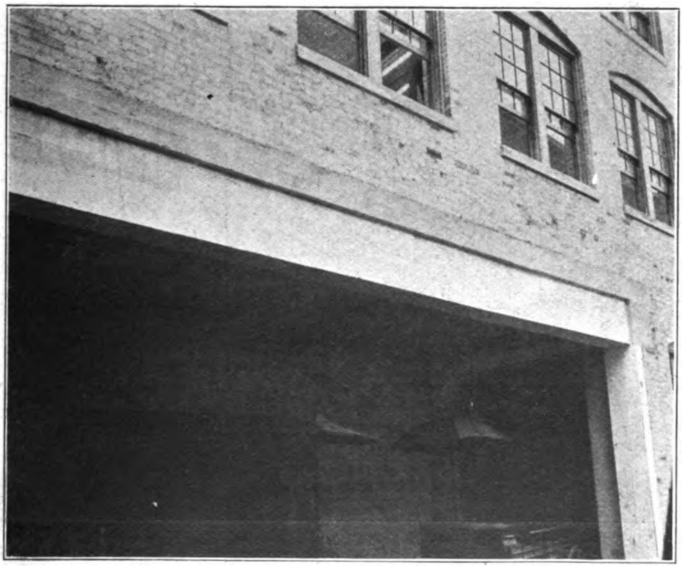


Fig. 14.—Lintel of 33 feet span, supporting a wall 60 feet high with several floors. J. H. Day & Co.'s Foundry, Cincinnati, O.

sections in this construction were 20 feet centers and square. We placed therefore on this girder 77,000 pounds, on a base as small as was practicable, with the object of approximating a concentrated load, and as before found that the girder showed above 75 per cent

of its ultimate deflection with about 1-3 to 1-2 load. The whole load of 77,000 rested on a span 6 feet square Under the entire load, the beam showed a maximum deflection of 2.6 MM, with no evidence of any greater deflection after the load had remained 72 hours.

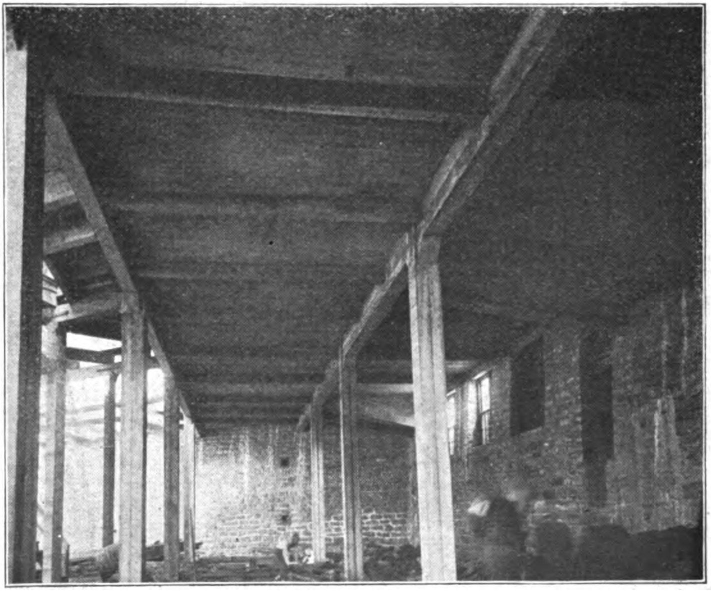


Fig. 15.—Floor of 20 ft. span, and Columns 26 feet high. J. H. Day & Co., Cincinnati,

Lastly, we selected the largest floor panel in the construction, viz.: one 12 feet wide by 19 1-2 feet long, and we loaded this with 38,000 pounds of pig iron on a base 4 feet wide by 19 1-2 feet long over the middle of the span. This load on a 375 pound basis should be about 43,000 pounds, however, after the placing of the load the deflection at the middle of the span was 1-8 of an inch.

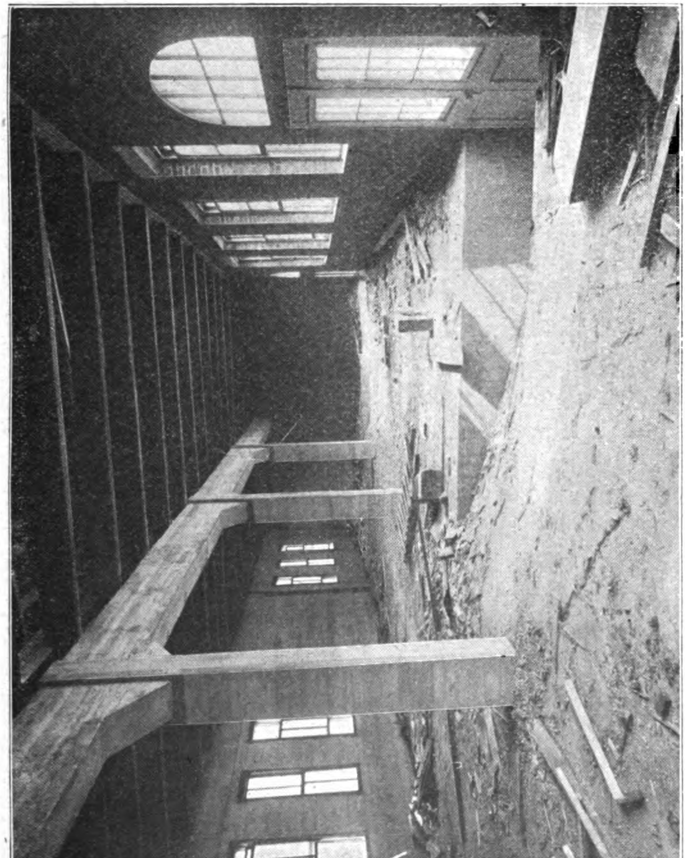


Fig. 16.—Columns and Girders to Support Temporary Roof. At the left are 4 inch Concrete walls with fireproof windows. J. H. Day & Co.'s Foundry, Cincinnati, O.

Hoping this report is satisfactory, we are,

Yours very truly,

THE J. H. DAY COMPANY,

(Signed) PAUL S. WARD,

Mech. Engr.

Messrs. Dittoe & Wisenall, Architects, Cincinnati O., write:

MR. L. J. MENSCH,

Chicago, Ill.

DEAR SIR: On May 20, 1903, we witnessed a test made on armored concrete girders and floor construction of the Hennebique system in the new warehouse for the Champion Ice Co., Covington, Ky., and which work was installed by you under our direction.

The girders were located 7 ft. 6 ins. apart, of 18 feet span and were figured for a superimposed floor load of 250 pounds per square foot. A floor area of 14x18 feet was loaded with 100,000 pounds, i. e., 400 pounds per square foot, and the maximum deflection reached 1-10 of an inch. These girders were supported by 10 inch columns and 4 inch concrete partitions and as the owners of the building were afraid of the column and partition construction, the 100,000 pound load was left upon the second floor and directly above the same, on the third floor, an area of 14x18 feet was loaded with 150,000 pounds, equal to 600 pounds per square foot, and the greatest deflection reached was 1-8 of an inch, and not the least sign of cracks or weakness in the columns or partition work could be discovered although both of these loads were allowed to remain in place for several days and upon the removal of the same, the floors and girders resumed their normal position.

We were very much gratified with the success of this test. The building has now been loaded for several months to its safe capacity with goods which were kept in cold storage during this season of the year, and the building is very satisfactory for this purpose.

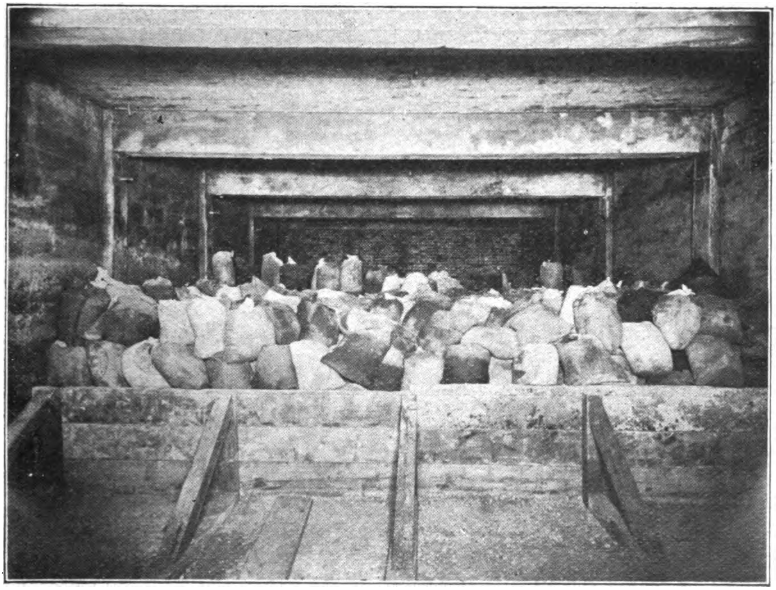


Fig. 17.—Test of Girders and Floor. Champion Ice Co.'s Cold Storage House, Covington, Ky. Load, 150,000 pounds; 400 pounds per square foot.

We believe this material and your system to be an excellent building material for buildings of this class and we wish you the success which your knowledge of its use certainly deserves.

Yours respectfully,
(Signed) DITTOE & WISENALL,
Architects

Fig. 18.—Test of Girders and Floor. Champion Ice Co.'s Cold Storage House, Covington, Ky. Load, 150,000 pounds; 600 pounds per square foot.

Fig. 19 shows a test of girders of the library floor of the new McKinley High School, Russell and Ann Aves., St. Louis, Mo., Wm. B. Ittner, Architect.

The girders tested spanned 32 feet. The entire floor of 32x36 feet was uniformly loaded with 264,000 lbs representing a load of 220 lbs. per square foot, that is, three times the figured load.

The deflections in the center of the beams were:

At a load of 105 lbs. per square foot....0.087 inches
At a load of 160 lbs. per square foot.....0.165 inches
At a load of 220 lbs. per square foot.....0.323 inches

Under three times the load the deflection was 1-1190 of the span; after removal of the load, there remained a permanent deflection of 0.118 inches.

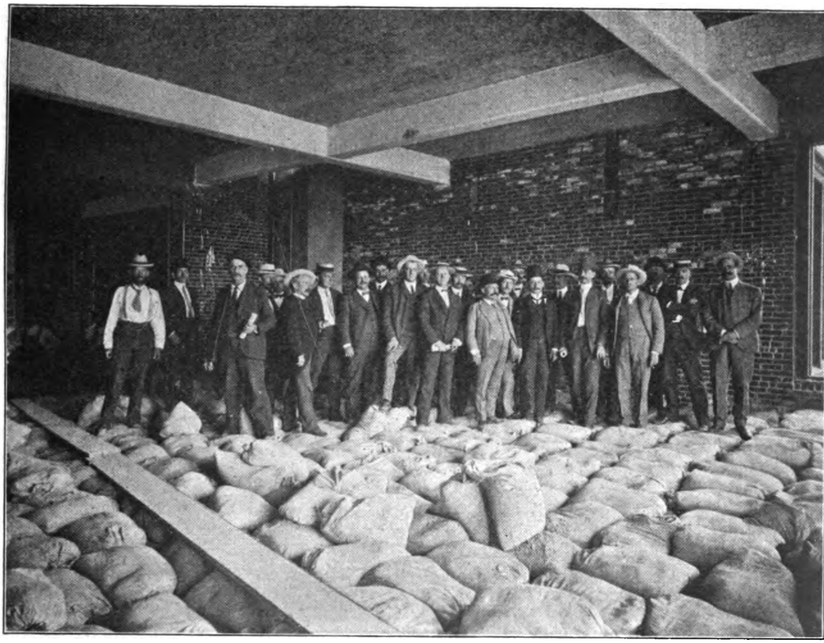


Fig. 19.—Test load, Library floor, McKinley High School St. Louis, Load, 264,000 pounds; 220 pounds per square foot.

We also refer to another very convincing test made on girders of fifty-seven feet span at the new Lyric Theatre, Cleveland, Ohio. These girders were figured to carry an uniformly distributed load from the balcony of 65,000 pounds, and were tested by hanging a load of pig iron of 88,000 pounds from the center.

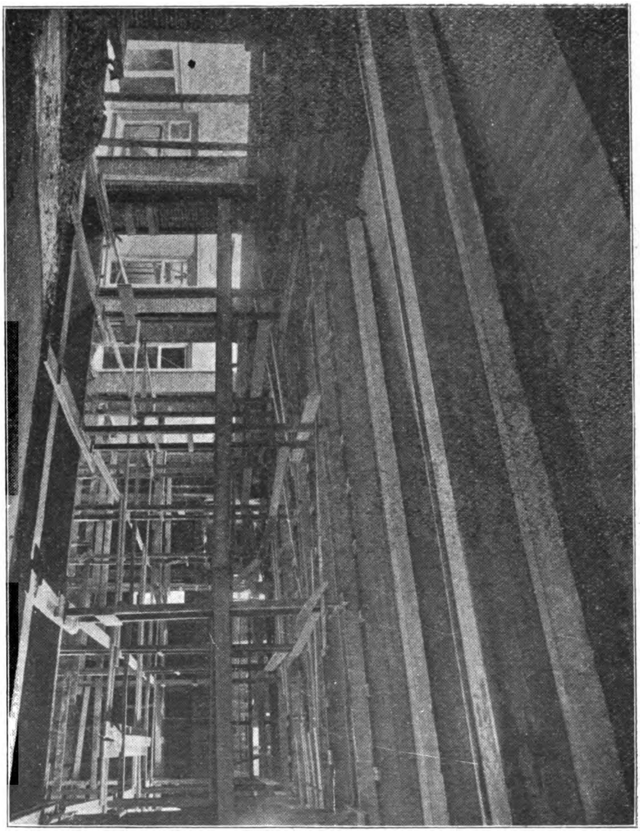


Fig. 20.—Roof and Balcony Girders of 50 ft. Span, Auditorium McKinley High School, St. Louis.

which is equivalent to a distributed load of 176,000 pounds. The greatest deflection was 9-16 of an inch and the permenant deflection was less than 1-8 inch.

CONSTRUCTION OF REINFORCED CONCRETE FLOORS.

The floor slabs connecting the beams or walls are generally from 2 1-2 to 6 inches thick and reinforced by 1-4 to 3-4 inch steel rods 3 to 12 inches on centers.

These slabs are usually continuous, therefore, tensile stresses are set up not only at the underside of the slab in the center of the span, but also over the supports in the top fibres, and the steel rods have to be bent in hog chain form, as shown in Figures 2 and 21, to take care of these tensile stresses. Sometimes it is even necessary to imbed short extra rods in the upper part of the slab.

For any given percentage of steel reinforcement, the carrying capacity of the slabs is proportional to the square of the height.

The following table gives the maximum live loads per square foot, which these slabs are able to carry with a factor of safety of four or five, when reinforced by a very high percentage of steel.

Thickness of slab in inches.	Span in feet.									
	5	6	7	8	9	10	12	14	16	18
3	450	300	200	140						
3½	600	400	280	200	140					
4		560	390	280	200	160	90			
4½		690	500	370	270	210	130	70		
5			640	470	360	270	170	100	60	
6				690	530	410	260	160	100	60

It is always more economical to use a greater depth than those given in the table; this reduces the amount of steel required and cheapens the cost of the floor.

It is advisable to use these slabs for spans not exceeding 8 feet for heavy load, say 200 lbs. per square

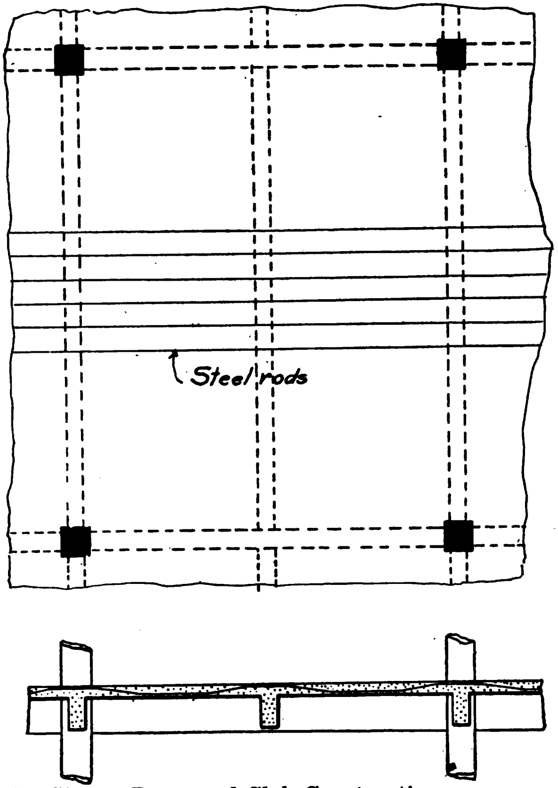


Fig. 21.—Girder, Beam and Slab Construction.

foot and over, and for spans not exceeding 12 feet for lighter loads, and adopt, where economy is the principle consideration, an arrangement of beams, girders and floor slabs as shown in Fig. 21.

Much greater spans can be adopted, when the floor slabs are nearly square and supported on all four sides as shown in Fig. 22.

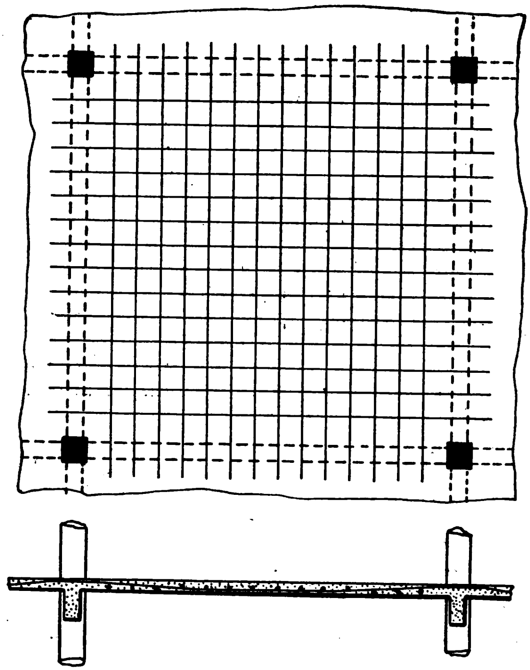


Fig. 22.—Girder and Square Slab Construction.

In this case the slabs are reinforced by steel rods in both directions, and the supporting girders have to carry only one quarter of the load of each panel, and as two panels usually meet over the beams, they have to be figured for half of the panel load, which loading is about a mean between a concentrated and a distributed load.

The following table gives the maximum live loads that nearly square slabs, reinforced by a very high percentage of steel in both directions, will carry with a factor of safety of four to five:

Thickness of slab in inches.	Side of square, in feet.								
	6	8	10	12	14	16	18	20	25
3	800	400	250	150					
3½		600	350	230	150				
4			550	360	250	180			
4½			800	480	360	250	190		
5				700	480	350	250	150	
6					730	540	400	300	150

Here also it is more economical to use greater depth than given in the table.

This arrangement of square or nearly square slabs lends itself easily to decoration, and is no more expensive for light loads, and very little more for heavier loads, than the ordinary slab and beam construction, and is a very appropriate arrangement for public buildings, department stores, etc.

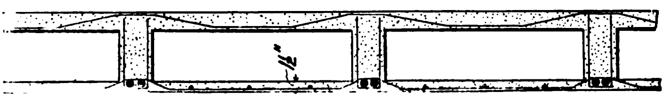


Fig. 23.—Section Through Hollow Concrete Floor.

Where flat ceilings for spans of more than 18 feet are required, a hollow floor construction, as shown in Fig. 23, gives very satisfactory results.

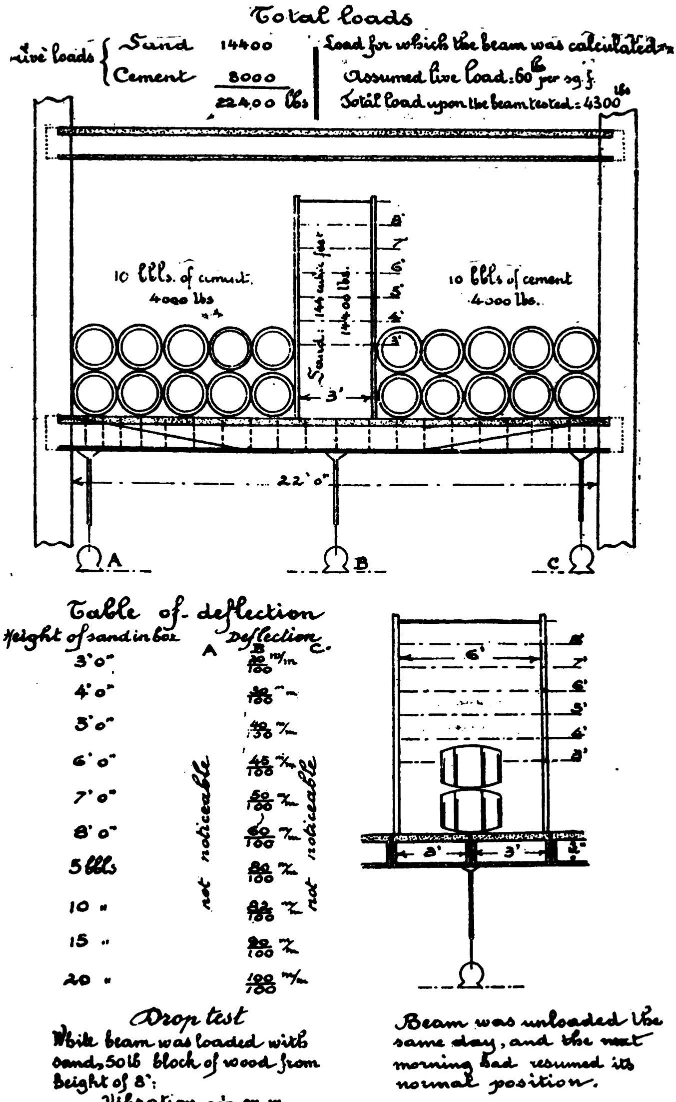


Fig. 24.—Test of Hollow Floors, Sheldon residence, New York City.

This floor consists of ribs 4 inches to 6 inches thick and about three feet apart, which are reinforced by straight and bent bars and stirrups, a 1 1-2 inch ceiling, strengthened by light steel rods in both directions and a 2 1-2 to 4 inch reinforced concrete floor. The depth of these floors is 10 inches for 18 feet spans, and 20 to 24 inches for 40 feet spans.

Fig. 24 shows the diagram of a test load on such floors of 22 feet span, at the Sheldon House, 38 E. 40th Street, New York City, in presence of the representative of Mr. Ernest Flagg, the architect, and engineers of the New York Building Department. The floor was tested to 350 lbs. per square foot, and the greatest deflection was 1-25 of an inch.

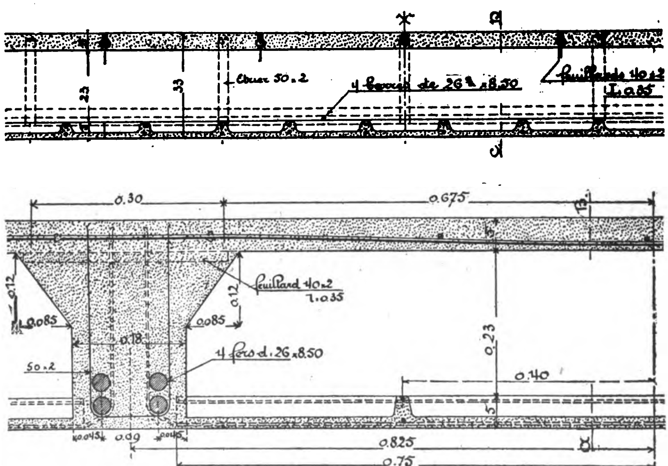


Fig. 25.—Section Through Girder and Floor Construction with Reinforced Concrete Ceiling.

The ceiling and the ribs are usually concreted first and the centering for the floor is obtained by wire netting, or arched match boards, or thin concrete plates,

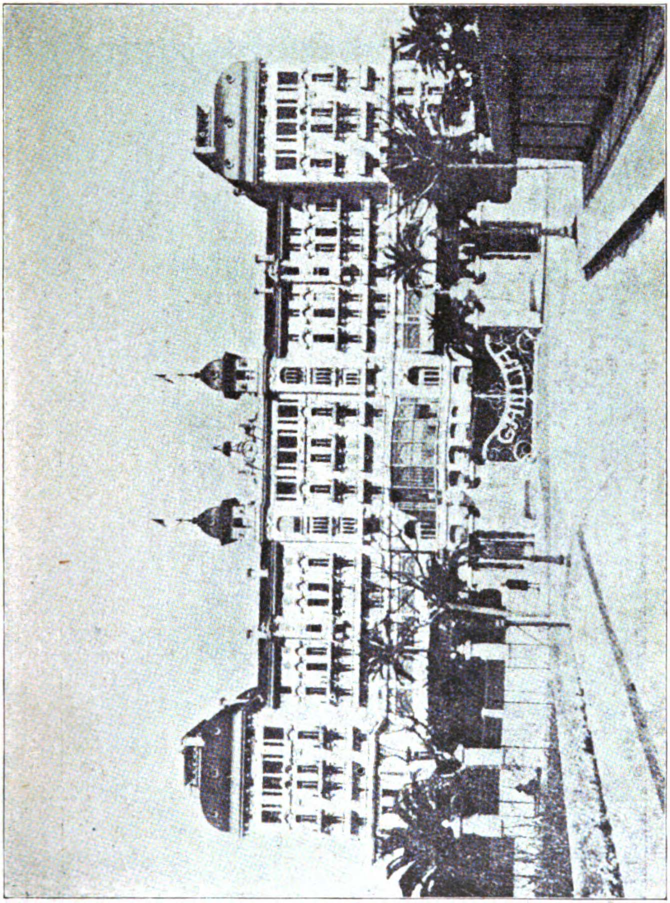


Fig. 26.—Hotel Gallia, Cannes, France. 80,000 square feet of floors of 27, 35 and 40 feet span.

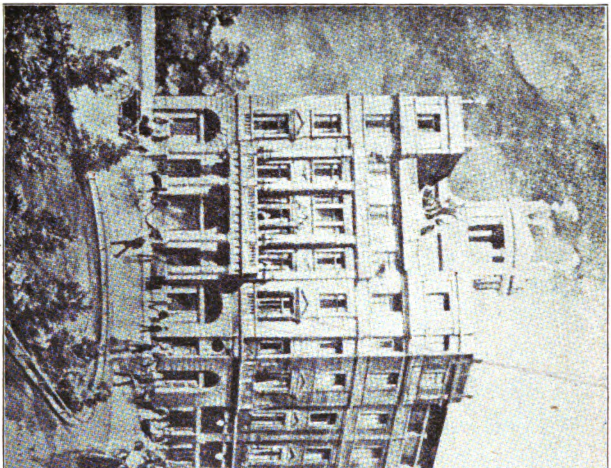


Fig. 27.—Hansa, Dusseldorf. 135,000 square feet of floors. Wall columns of reinforced concrete.

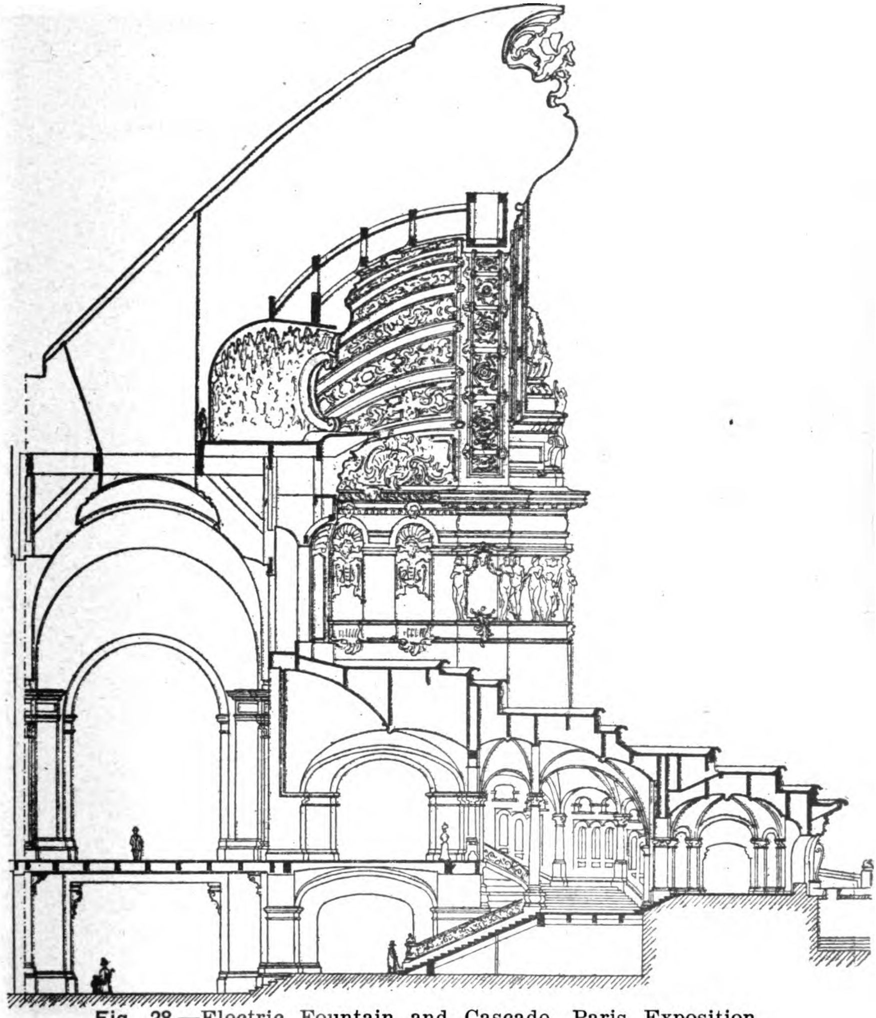


Fig. 28.—Electric Fountain and Cascade, Paris Exposition, 1900. **The most elaborate structure of armored concrete ever erected. 140 feet high.**

etc. These hollow floors are of great advantage in cold storage houses, as a less conductive floor construction can hardly be imagined.

The centering for floor slabs may be removed eight days after concreting, if the weather was moderate during this time; but when the temperature has been near the freezing point it is advisable to wait 14 days with the striking of the forms. Most of the accidents which happen in concrete construction are due to the fact that the centering was removed before the concrete had sufficiently hardened.

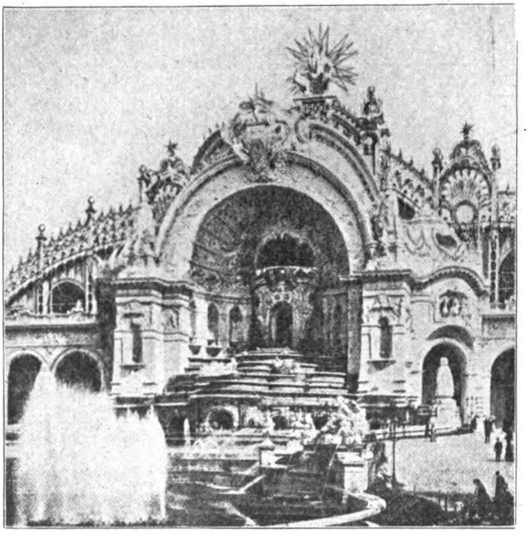


Fig. 29.—Front View of the Same.

In warm and dry weather, the upper layer of the concrete slabs sets up very quickly while the interior remains soft, resulting in fine cracks in the surface. To prevent this, the floors must be sprinkled, at least

every two hours, for a few days after concreting. These cracks appear very soon where the floors are exposed to the direct rays of the sun. This must be guarded against by covering the concrete with cloth and sprinkling it very often with water.

Frost retards the setting of the concrete. The water freezes and the cement cannot enter into the chemical union with the water. Frozen concrete will be found green in the inside after months of exposure; the cement has not been destroyed, however. If the concrete is sprinkled with water, once the temperature is again above freezing, the water will soak into the concrete, and the cement continue to set. This sprinkling should be continued for at least a week. Repeated freezing and thawing will usually destroy concrete, which is not more than 14 days old. The water by freezing expands and ruptures the concrete. Therefore, if concreting has to be carried on in weather near the freezing point, all exposed surfaces should be covered with cloth and a layer of sand.

FINISH OF CONCRETE FLOORS.

The most common method of finishing concrete floors is by laying bevelled 2 in. x 2 in. sleepers, 16 in. centers, on the concrete floor, and by weighing down these sleepers by a 1 1-2 inch layer of cinder concrete and nailing the wood floor on the sleepers as shown in Fig. 30.

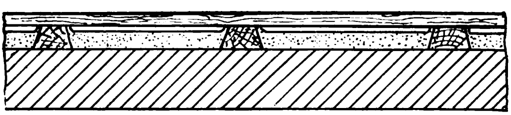


Fig. 30.—Wood Floor on Concrete Slab.

We secure a half inch air space, which makes the floor much more sound and heat proof.

The cinder concrete should be mixed in the proportion of 3-4 barrel of Portland cement (though one barrel of Hydraulic cement also gives good results) to one yard of cinders with a moderate amount of water. If too much water be used the sleepers will absorb the water and warp. Careful builders usually hold up the sleepers by planks and uprights against the ceiling to insure a good job.

For factories, storage houses, etc., the concrete floors are generally finished by a half to 3-4 inch coat of cement mortar, cement and sand being mixed in the proportion of one to two. This wearing surface should be spread on the concrete while the latter is still soft and adhesive. If this cannot be done at this time, the surface of the concrete should be scraped and thoroughly cleaned and well sprinkled with water and afterwards with neat cement before the finishing coat is applied.

Granitoid finish is used for corridors of public buildings, and is a wearing surface, generally one inch thick, composed of one part Portland cement to 1 1-2 parts of crushed granite, in size from 3-8 inch down.

Cracks in the cement finish are prevented by dividing the wearing surface along the main girders.

Hotels and apartment buildings where the floors are covered by heavy carpets need no other finish whatever, only special care has to be taken to have the surface of the concrete floor fairly smooth. In this case nailing strips can be imbedded in the concrete to fasten the carpets, and eventually some finish provided on the sides of the rooms or corridors for a margin.

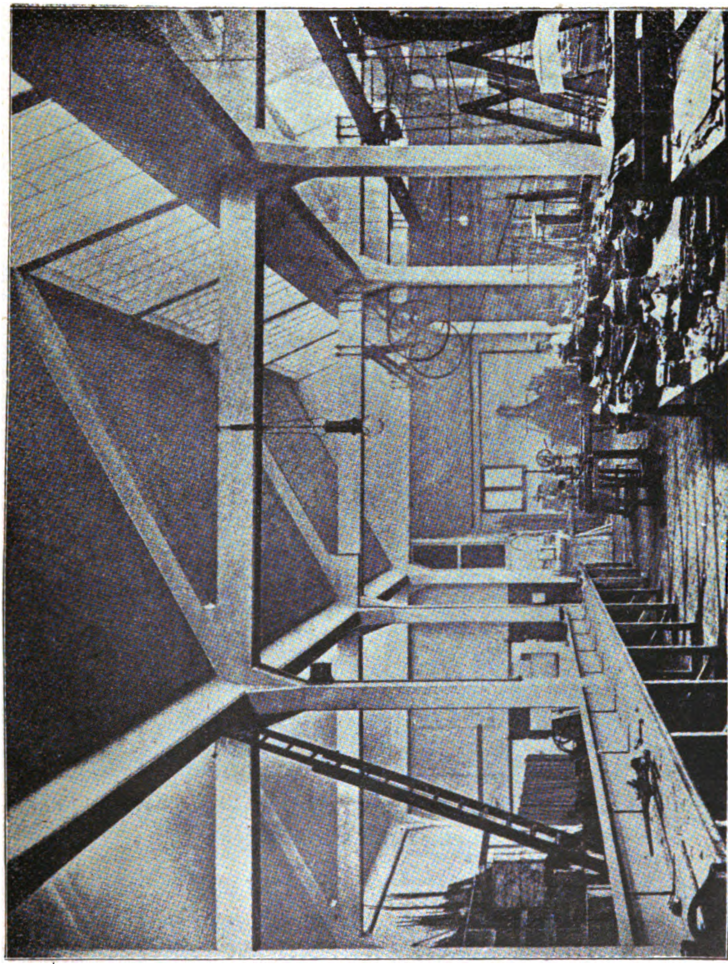


Fig. 31.—Shed Roof of Armored Concrete. Distance of Columns 20 feet.

Lime plaster adheres firmly to concrete work and the illustrations show some highly ornamental plaster work in this line.

RE-INFORCED CONCRETE ROOFS.

The roof construction is similar to that of floors only that the construction is generally much lighter. It is, however, not advisable to reduce the thickness of the floor slabs below 3 1-2 inches to avoid cracking.

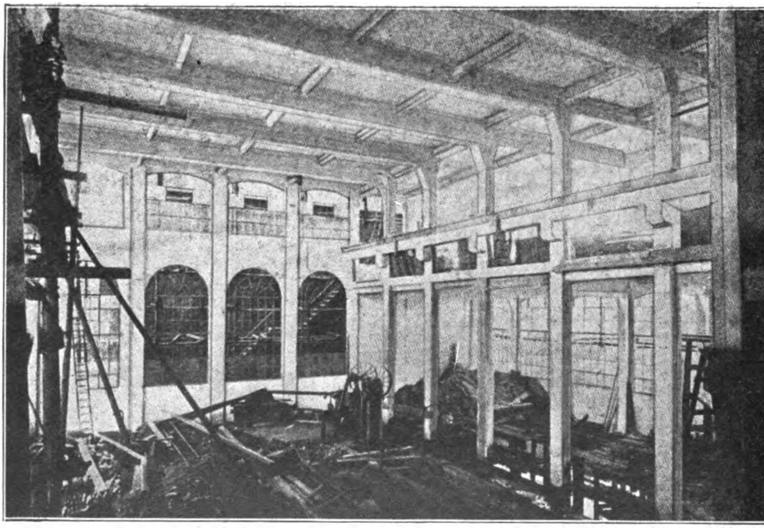


Fig. 32.—All-concrete Foundry, Hull, England. Unusually well lighted. Span of girders, 40 feet.

Roofs are exposed to great and often sudden changes of temperature and must be guarded against cracking by imbedding plenty of steel rods in both directions in the slabs.

Concrete roofs are not water proof by themselves. They must have a water proof covering. A reliabl

and inexpensive covering is a tar and gravel roof which can be laid directly on the concrete surface of the roof, without any intermediate wood floor. A more expensive covering, yet a very durable one, is a one inch layer of asphalt.

Another method, which is, however, not to be recommended, is by spreading a one inch coat of cement mortar, composed of 1 part cement and 1 1-2 parts of sand on the concrete. Only very experienced workmen can do a good job, and it is safer first to paint the surface of the concrete floor, with a water proof asphalt paint, for example, Toch Bros.' R. I. W. paint, and spreading on the thus prepared surface, the cement finish.

The cement coat preserves the asphalt paint which soaks into the concrete, and adheres to it with great force, and makes it water proof, and should the cement finish crack, the water, which may come through the crack, cannot soak into the concrete of the roof.

The lowest layer of the roof slabs should be made of a rather porous concrete in order to absorb the moisture which arises there from condensation, thus preventing drops falling from the ceiling.

Concrete roofs built in Cleveland, Cincinnati, and other places, gave no cause of complaint in this direction.

WEIGHT OF CONCRETE FLOORS.

The weight of one square foot of concrete one inch thick is 12 lbs. Therefore, the weight of a concrete floor per square foot is found by multiplying the thickness of the concrete in inches by 12 and adding 15 lbs. for sleepers, cinder concrete, wood floors and plastering.

FLOOR LOADS.

Very careful consideration of the floor loads to be specified for a building will often save a considerable amount of expense. Floors for residences do not require to be figured for more than forty pounds per

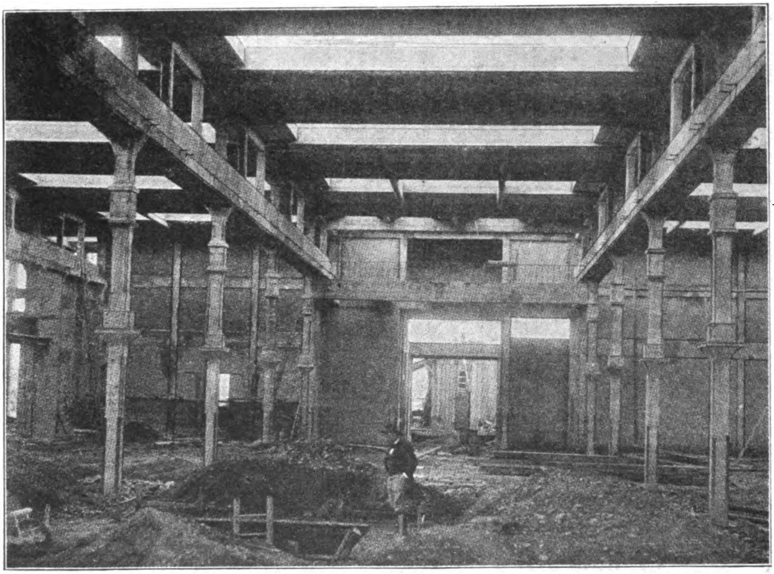


Fig. 33.—Foundry Building of Armored Concrete Construction. The columns support a track for a 30 ton traveling Crane. Note holes in columns for attaching bearings of radial drilling machines.

square foot. Experiments made in Boston demonstrate that the live loads in office buildings are rarely more than fifty pounds per square foot and do not generally exceed more than ten pounds. Therefore, it will be good practice to figure the floor slabs for 60 lbs. per square foot; this will allow a good margin

for heavy safes or similar loads. A reduction of floor loads can be made for the girders and a still greater reduction for the columns—as experience has repeatedly demonstrated that floor loads vary only from 10 to 50 pounds. School buildings do not require to be figured for more than fifty to sixty pounds per square foot.

Department stores, warehouses, and factories have floor loads which vary considerably. It is to be borne in mind, however, that in all these cases only a small part of the floor area is really loaded with the heaviest class of goods or machinery, and that there are usually many aisles and cross aisles taking up as much as twenty to fifty per cent. of the floor area.

If, for example, a live load of 150 pounds per square foot is specified, it means that all columns, girders, beams and slabs have to be figured for a load which is equal to the area carried by these members multiplied by 150. Very often this load of 150 pounds is specified for very light manufacturing purposes, which is only a waste of money, as in a panel 14 feet square, for example, there will probably never be anything near to 30,000 pounds which this specification would require.

The writer determined the live loads in one of the heaviest hardware houses in Cleveland, Ohio, and found that the average load on the top floor was not more than forty to fifty pounds per square foot; and on another floor loaded with enamel ware, scales, shovels in bundles of twelve pieces, which materials weigh about 150 pounds per square foot, the average load was not more than 100 pounds.

Floors loaded with axes, picks, barrels of hinges and barrels of tacks, weighing about 500 pounds per

square foot had an average distributed floor load of not more than 250 to 300 pounds. The ground floor, loaded with butts, tin plates, sixteen boxes high, gas pipes, etc., weighing 900 pounds per square foot, had an average floor load of 500 to 600 pounds..

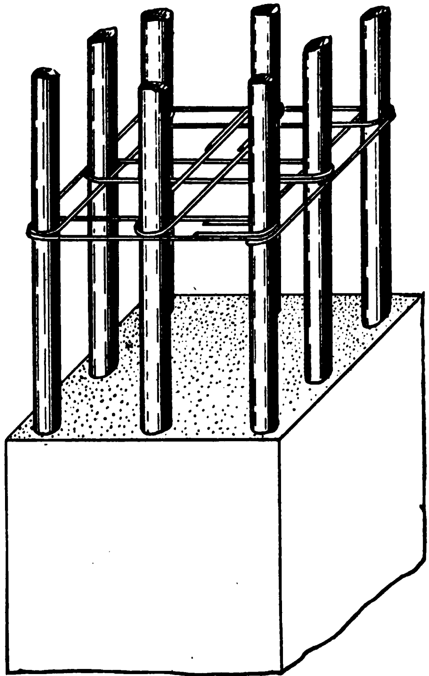


Fig. 34.—Armored Concrete Columns.

CONSTRUCTION OF REINFORCED CONCRETE COLUMNS.

Concrete columns are reinforced by 4, 6, 8, up to 20 or more steel rods in diameters from 3-8 inch to 2 1-2 inches. As seen in Fig. 34, the rods are placed near the circumference, give therefore the largest radius of gyration, and are in a position to take up tensile stresses, which may be produced by excentric loading, wind pressure, pull of beltings, or lateral shocks. The strength of these columns is the sum of the strength of the concrete plus the strength of the steel rods, and as the concrete is here more carefully rammed than in other concrete work, we can safely allow 300 to 400 lbs. per square inch in the concrete. The stress in the steel rods may be computed by the same rule as for ordinary steel columns. These columns fail mostly by the shearing of the concrete under 45 degrees, (see Fig. 35) and by pushing the steel rods apart, therefore, we have to connect the different steel rods by ties in intervals of not more than the diameter of the column. The following table gives the maximum loads which square columns, not exceeding in height 15 times the diameter, will carry with a factor of safety of four to five:

Side of square in inches	8	10	12	14	16	18	20	22	24	30	36
Maximum load in 1000 lbs	90	140	215	285	380	480	600	720	850	1350	1800

It is always more economical to use larger columns than indicated in this table.

The columns can be made of any shape, rectangular, octagonal, round, etc.; pipes may be imbedded for water, gas or electric wire conduits.

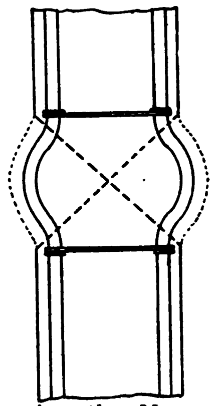


Fig. 35.—Sketch Showing the Manner in which Columns Fail.

Reinforced concrete columns are nearly 30 per cent cheaper than cast iron columns without fire proofing and are much more reliable than the latter, proof of which we cite, the test at the S. A. Citadel where a girder which was connected on one side to a girder and on the other side to a column, was loaded to four times the capacity, i. e., 100,000 lbs., and transmitted therefore an excentric load of 50,000 lbs. on the column; the test at the office building and warehouse of the Davis Sewing Machine Co., where a beam of 27 feet span, connected at one side to a ten inch column, produced an excentric loading of 62,000 lbs., and the very severe column tests made at the Palais de Costume at the last Paris Exhibition.

The building was entirely constructed in armored concrete. The columns were twenty feet apart, and of such small diameter, that the authorities doubted their resistance to eccentric loading, and prescribed a test, consisting in a load of sand weighing 150 tons, or one and one-half times the load, for which the columns were designed, to be applied on alternate panels of the two stories (Fig. 37). The lateral spring of the columns could hardly be measured and was a minute fraction of 1-32 of an inch.

The columns are concreted in forms, consisting of three side pieces, while the fourth side is left open

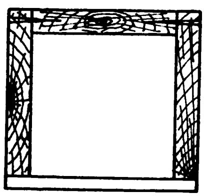


Fig. 36
Forms for Columns.

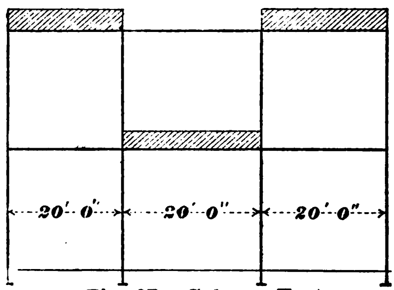


Fig. 37.—Column Test.
Palais de Costume.

(Fig. 36). The concrete is rammed in layers of a few inches, with special small rammers, and the open side boarded up as the concreting progresses. This enables thorough inspection of the work and facilitates the placing of the ties in proper distances.

The forms may be struck a few days after the concrete is placed; in this case the columns should be sprinkled with water in warm weather to prevent where no plastering is required, it is well to put tri- checking of the surface. In factories and warehouses,

angular strips in the corners of the forms, to obtain a beveled edge, which prevents the breaking off of the otherwise sharp corners.

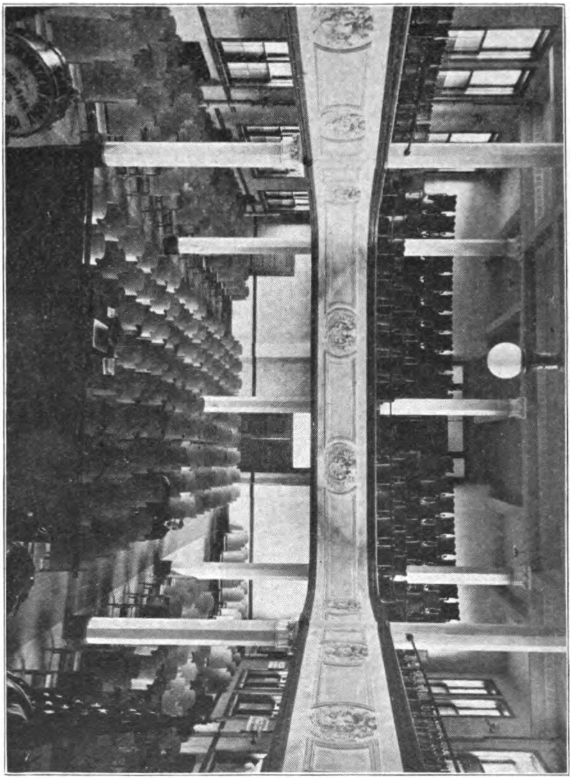


Fig. 38.—Octagonal Columns, Auditorium, Salvation Army Building, Cleveland, O.

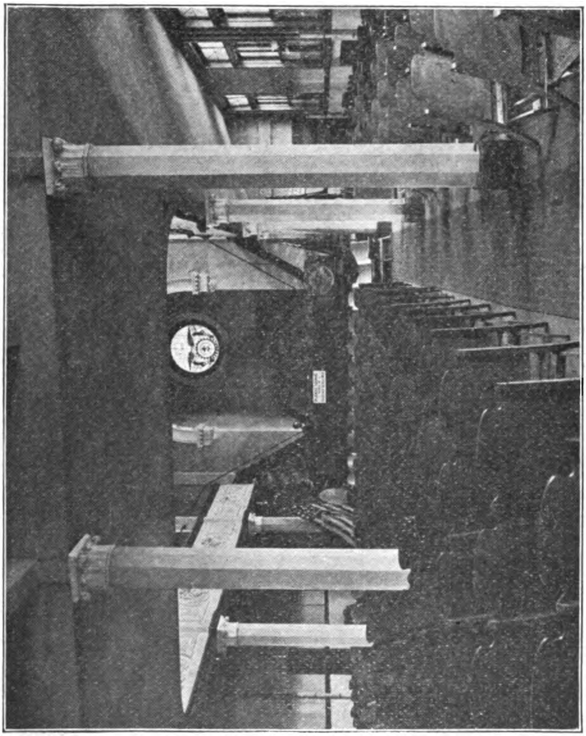


Fig. 39.—Balcony of Reinforced Conc rete. Auditorium, Salvation Army Building, Cleveland, O.

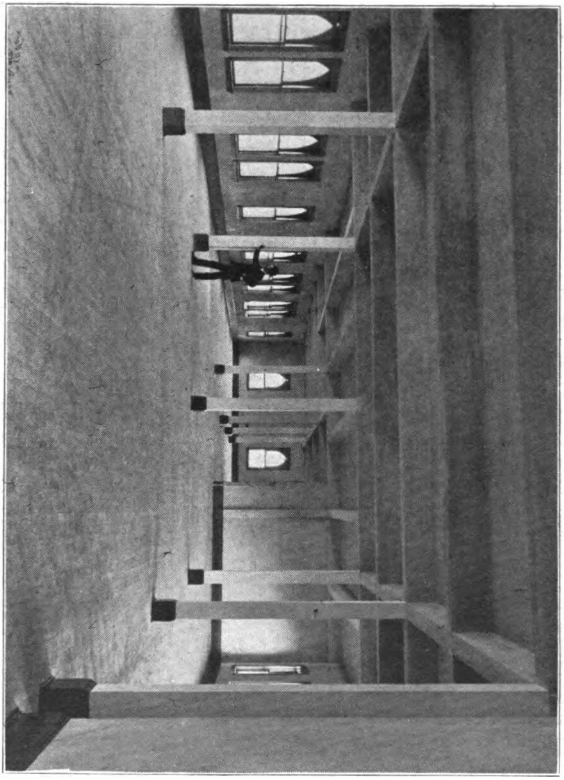


Fig. 40.—Columns and Girders in an upper floor. Span, 24 feet. Salvation Army Building, Cleveland.

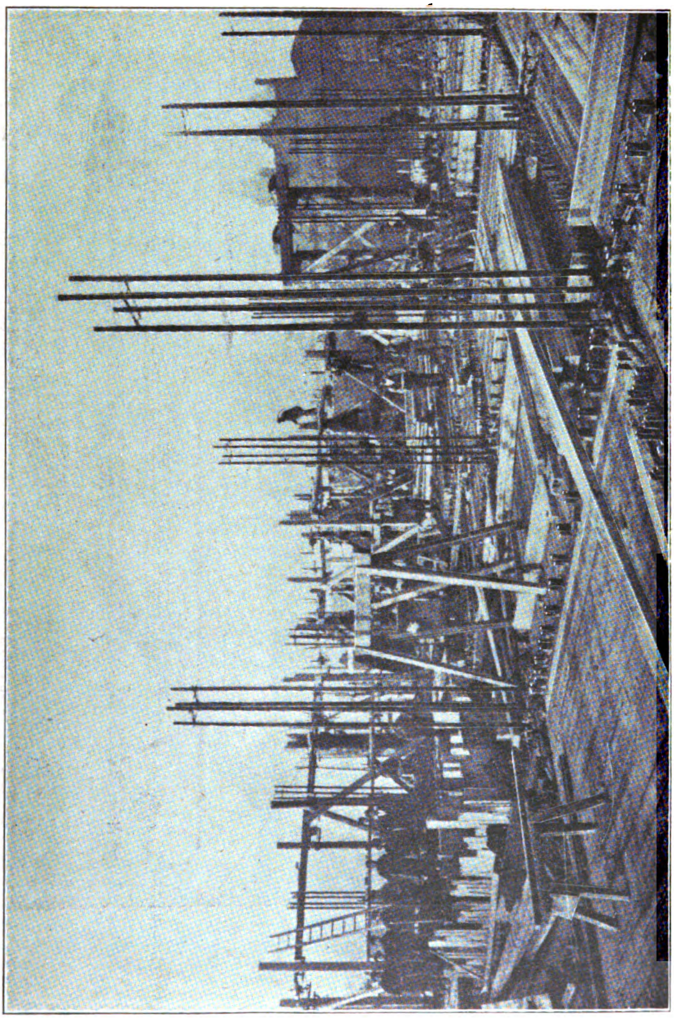


Fig. 41.—Concreting of Girders, Floors and Columns. Column rods extend through 2 stories.

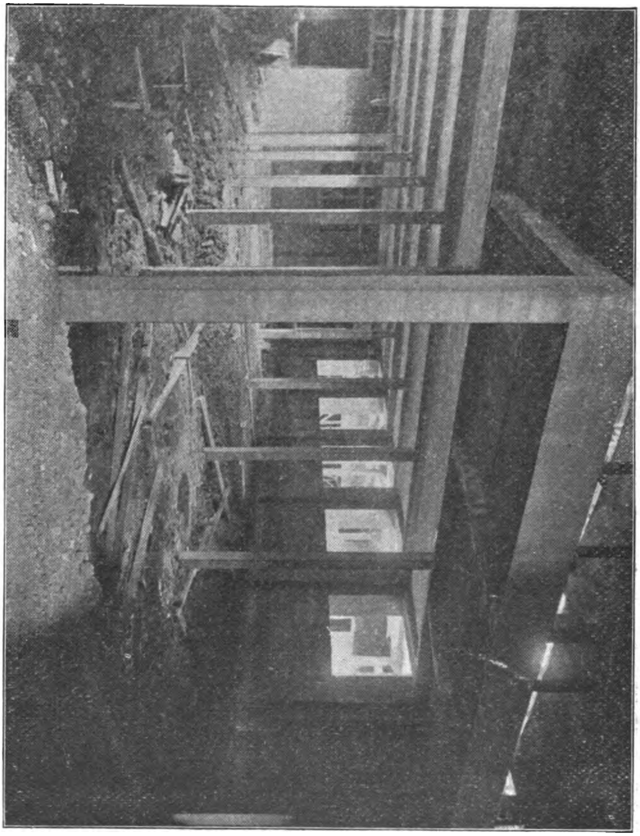


Fig. 42.—McKinley High School, St. Louis. Columns Supporting Auditorium Floor.

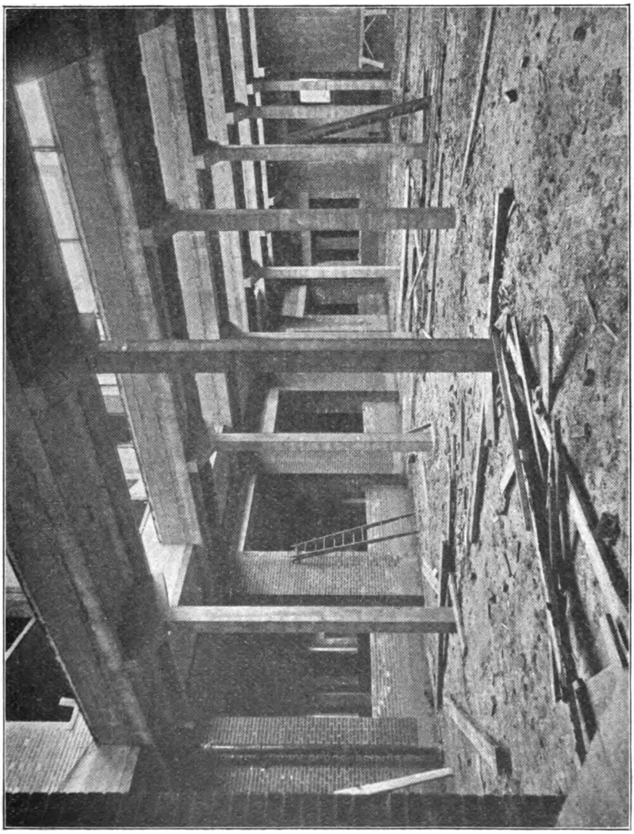
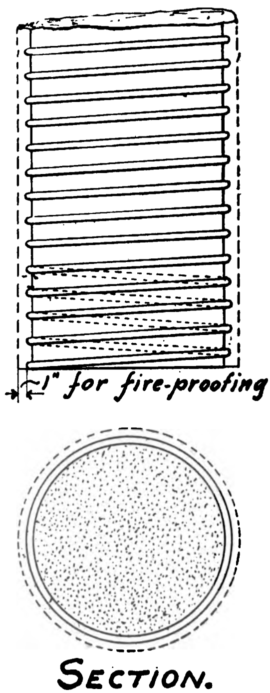


Fig. 43.—McKinley High School, St. Louis, Mo. Columns and Hollow Girders Supporting Sky-light of Machine-shop.

CONSIDERE COLUMNS.

By inspecting above table of loads for various sizes of columns, it will be found that the size of the latter are in most cases smaller than the size of fireproofed steel columns. There exists, however, another method



ig. 44.—Considere Columns.

of reinforcement, by which the size of the columns can be very considerably reduced. This method was invented by Mr. Considere, Chief Engineer of the French Government Bureau, for the investigation of armored concrete construction. He made thousands

of tests on round concrete columns, reinforced, by rods in sizes from 1-4 inch to 3-4 inch, which were wound in a spiral with close steps around the surface (Fig. 44). He found if the steps of the spiral is less than 1-7 to 1-10 of the diameter, that such columns have without any longitudinal reinforcement, an ultimate resistance of 12,000 to 15,000 lbs. per square inch of sectional area of the concrete.

His tests also indicate that if we reinforce concrete by spirals and by longitudinal rods, we can safely allow an average compressive stress of three to four thousand pounds per square inch on these columns, which would mean that a 20 inch round column can easily carry a load of one million pounds. These columns do not fail by shear, but by bending and show a surprisingly great ductility, many even very short specimens bending into an "S" shape, when the ultimate load was reached. They give ample warning before failure, the surface of the concrete begins to scale long before the limit of capacity is reached. There is no doubt that these columns will be extensively used for heavy loads, where small sized columns are preferred. It is not advisable to use them for light loads; this would reduce the size of the columns to such an extent that their appearance would be very frail. Besides they are much more expensive for smaller loads than the square or rectangular columns.

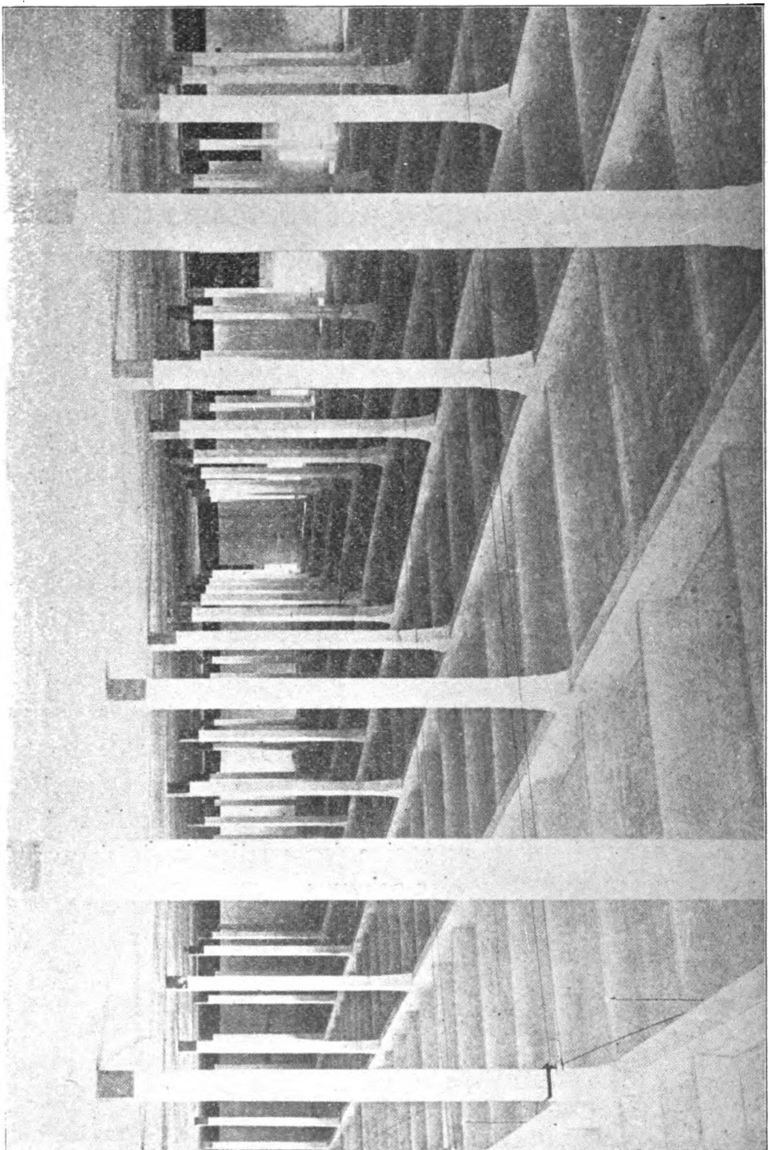


Fig. 45.—Sugar ware-house with an area of 60,000 square feet. Roof is covered with 4 feet of earth.

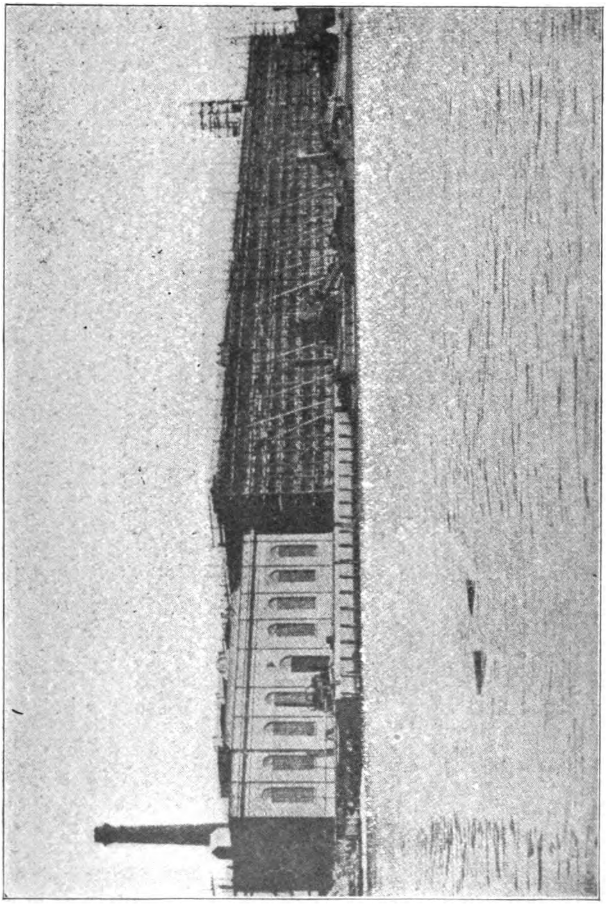


Fig. 46.—Cold storage ware-house and power house, Southampton, England. Built entirely of armored concrete. Size 400x120 ft. Roof of power house has a span of 50 feet and with the parapet wall forms a tank.

Fig. 47.—Interior of Cold Storage Ware-house.

CONSTRUCTION OF REINFORCED CONCRETE FOOTINGS.

Fig. 48 shows a typical wall footing. It can be considered a cantilever to both sides of the wall and figured on the same principle as floor slabs. The height of these footings rarely exceeds 1-4 to 1-5 of the width, thus saving a considerable amount of excavation and the cutting into the hard crust which generally overlies the yielding stratum. In connection with

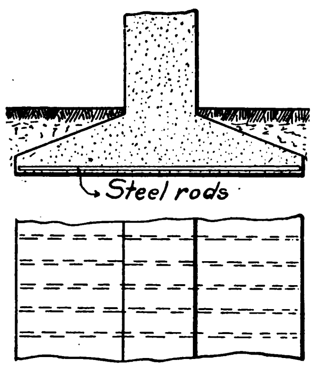


Fig. 48.—Reinforced Concrete Wall Footing

concrete basement walls, these footings form a huge girder, which will easily transmit the wall loads to a considerable length, should one part of the soil be less resisting than another. In case of newly filled up ground for considerable depth, this kind of foundation, if only 1,000 to 1,500 lbs. pressure per square foot is

allowed on the ground, will be much cheaper and very often safer than pile foundations. Fig. 49 shows a column footing designed on the same principles. It

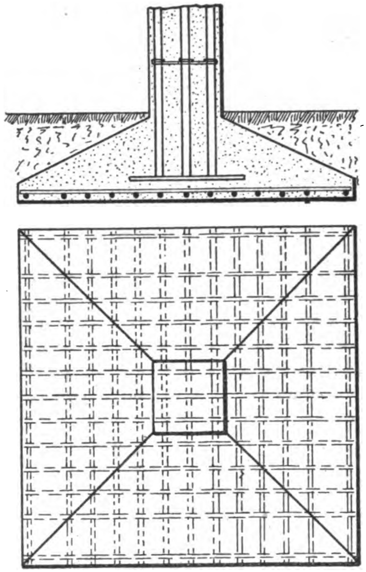


Fig. 49.—Reinforced Concrete Column Footing.

can be considered a cantilever on four sides and the steel rods cross each other at right angles.

The largest footing built on this order is a square of 70 feet length of sides.

Figures 50, 51 and 52 show quite a departure in concrete foundations. They illustrate an all-concrete warehouse with floor loads up to 800 lbs. per square foot, built for the Co-operative Wholesale Society, Limited, at New Castle-on-Tyne.

The building rises to a height of 120 feet above the quay level, on which it abuts, and consists of basement,

ground floor, and six upper floors, being in all eight stories in height from the foundation level to the roof. It occupies a frontage of 92 feet to both the Quay side

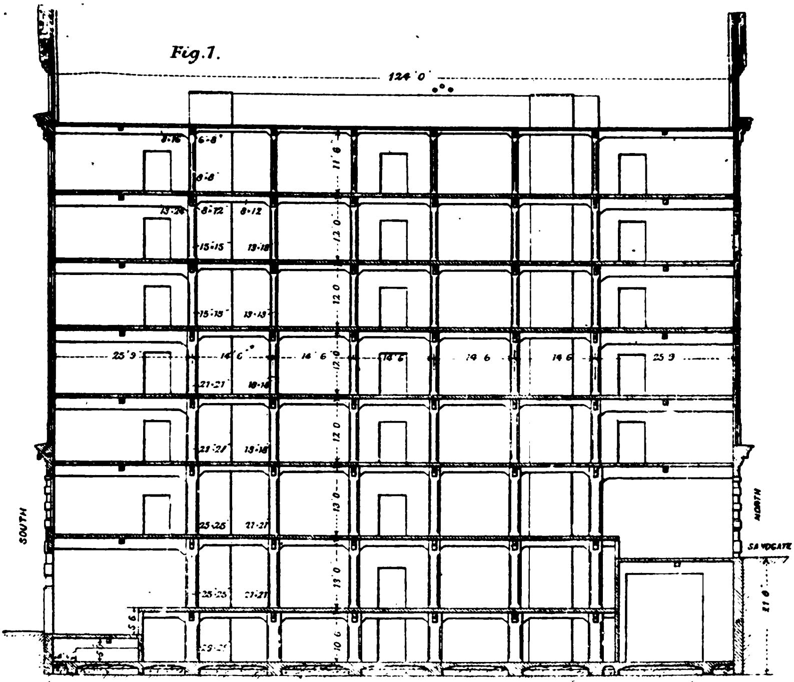


Fig. 50.—Section through Armored Concrete Ware-house, New Castle-on-Tyne.

in the front and Sandgate in the rear, and the depth from back to front measures 125 feet.

The principal difficulty which the architect of the Co-operative Wholesale Society had to face was that the ground at the site of the building was of the worst description imaginable for foundations. It consisted of the following: Eighteen feet of made ground, prin-

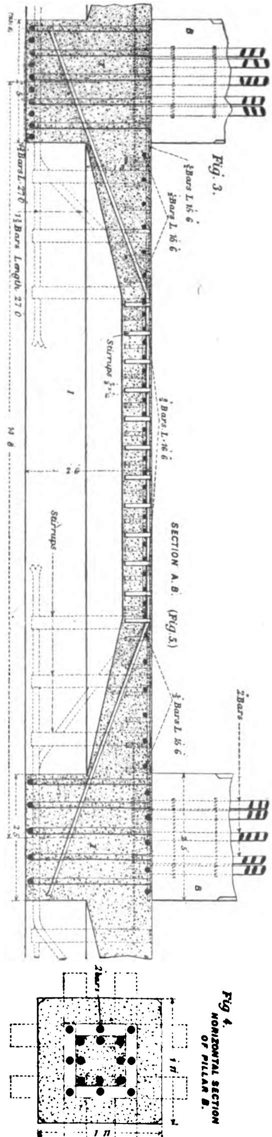


Fig. 51.—Section through Concrete Raft.

cipally clay; eighteen feet of silt and quicksand, ten feet of soft clay, five feet of hard clay, ten feet of silty sand, and finally of gravel. And to add to this difficulty, the above stratification had a pronounced dip to the River Tyne. It was obvious from the start that the foundations would have to be of an abnormal character to carry with safety the enormous weight

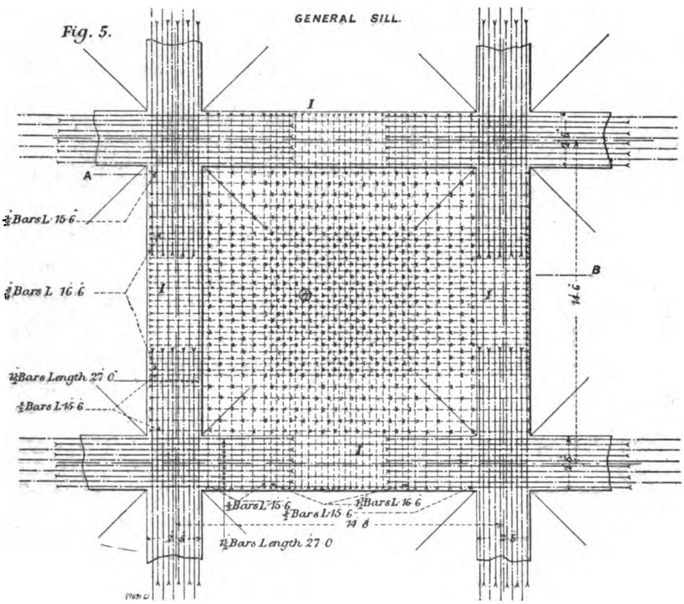


Fig. 52.—Plan of a Raft Panel.

superimposed by the projected building, which at first it was intended to construct of brick on a foundation of cylinders seven feet six inches in diameter sunk to a depth of sixty-two feet below the ground level of the Quay side and twenty feet below the ground level at the Sandgate side, carrying a raft of concrete four feet thick, with rails embedded therein. Another alterna-

Fig. 53.—Ware-house, New Castle-on-Tyne, with Floor Loads of 800 pounds per square foot.

tive considered was the driving of piles to the same depth, but the danger of injury to the neighboring property caused that method to be abandoned. Finally, the Co-operative Wholesale Society resolved to adopt their architect's recommendation to have recourse to a raft of ferro-concrete over the whole area of the ground. This raft, as constructed, measures two feet six inches in its thickest part and only seven inches in its thinnest part, and the idea of sinking piles or cylinders was thus abandoned, it being found that the ferro-concrete system would effect a great saving both in cost and time.

The construction of the raft is well shown in Figs. 51 and 52. Each column rests on two intersecting beams 2 ft. 5 ins. by 2 ft. 6 ins. deep, which divide the area of the building into rectangular panels, and which beams in conjunction with concrete arches, seven inches thick in the center, transmit the column loads over the whole available area. These heavy beams are able to transmit the loads for several panels, if there is a settlement at any particular point. It is clear that by making these girders five to six feet deep, we can without much greater expense carry the column loads over two to three panels, even if the ground disappears under a whole panel. In the warehouse mentioned an unequal settlement took place between the date of construction of the footings and the date of the construction of first floor, being 3 1-2 inches in the front and 3 inches in the rear. Since then, no further settlement has taken place. It is remarkable to note that in this building some panels of 200 sq. feet area have been tested to 96 tons, the severity of which test will be recognized when it is remembered that the heaviest

class of locomotive with tender could have been supported on a floor panel 14 feet square.

Fig. 54 shows the support of a brick wall on armored concrete girders and columns, which is a very economical arrangement, where the good ground is found at a reasonable depth below the basement floor.

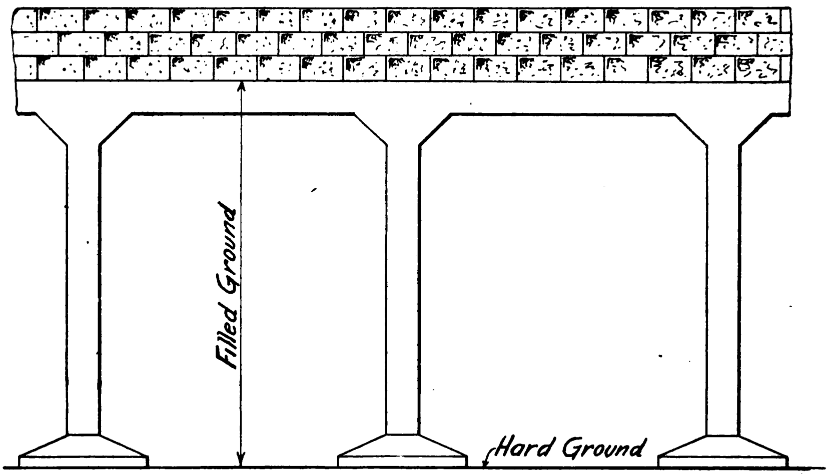


Fig. 54.—Wall carried on Isolated Reinforced Concrete Piers.

CONSTRUCTION OF REINFORCED CONCRETE PILES AND SHEET PILES.

Concrete piles have great advantages over wooden piles. They are neither affected by the rise and fall of ground water or by sea water, nor can they be attacked by torredoes, which in certain parts of the world destroy wooden piles in a very short time.

These piles are manufactured in molds, at least thirty days before use and the concrete is strengthened by steel rods of suitable dimensions connected at short intervals by stirrups (Fig. 55). At its lower end the pile is armed with a pointed shoe with side plates, the ends of which are turned in, so as to lock the pile securely in place. The head of the pile is of less width than the body, allowing a clearance between the heads of two adjacent piles. In order to insure uniform blows from the hammer in process of driving, and to prevent injury to the pile, the head is protected by a cap of cast steel and closed at its lower end by a clay ring held by a plug of hemp or spun yarn. This cap is previously filled with dried sand. A very regular cushion is thus formed on and all around the head, which cushion distrubutes the pressure in an absolutely uniform manner. This arrangement renders it permissible for the iron rods to project beyond the head of the pile, so that, in case of need, they may be connected with other parts of the structure or bent into hooks for convenience of handling.

The sheet piles (Fig. 56) are strengthened by four rods, connected by wire clamps, which, in their turn, are cross-tied by flat irons. At the lower end we have again a shoe, and the head is again of less width than

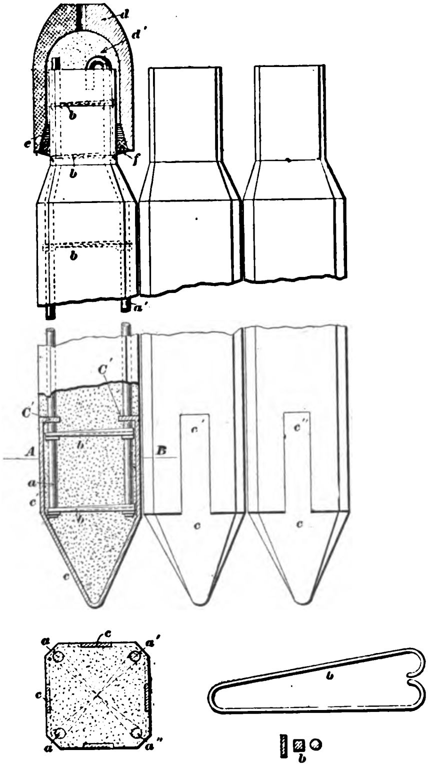


Fig. 55.—Details of Reinforced Concrete Piles.

the body, allowing room for the insertion of a cap. About 6 inches above the shoe on the longer of the narrow sides a projection is formed, while the remainder of both narrow sides is grooved for the entire length. The projection on one of the piles slides in the groove of the sheet pile last driven .

A special arrangement is provided to insure the desired direction of driving. An iron pipe which fits the groove of the sheet pile last driven, and that of the pile which is being driven, connects, by means of a hose, with a pump or water tank. This pipe serves as guide, and the water forces out the sand which might jam the grooves, thus facilitating the driving of the pile. Once the pile is down to the desired depth,

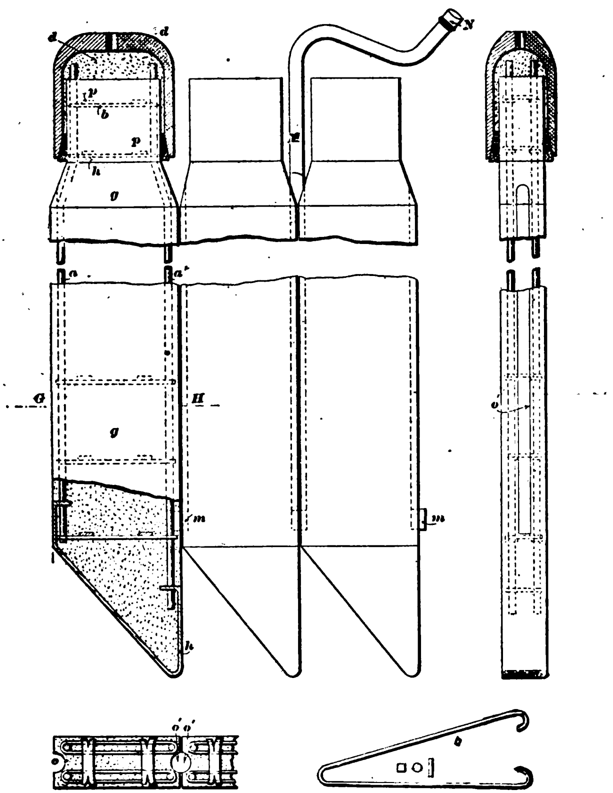


Fig. 56.—Details of Reinforced Concrete Sheet Piles.

the pipe is withdrawn, cement is run between the grooves and a perfect water-tight joint and wall are established. Tongue and groove joints are also sometimes used.

Fig. 57—Sheet Piles, retaining bank 6

These are splendid members of construction for marine work such as wharves, docks, jetties, etc. Of course, such structures have to withstand blows from vessels, but owing to the elasticity of reinforced concrete, the damage caused is certainly less than in the case of wooden piles and can be more easily repaired.

Masonry as applied to dock and harbor work presents numerous drawbacks, amongst those commonly met with being the settlement of heavy walls owing to the instability and uncertainty of foundations. In most cases they rest on alluvial ground, hence, the

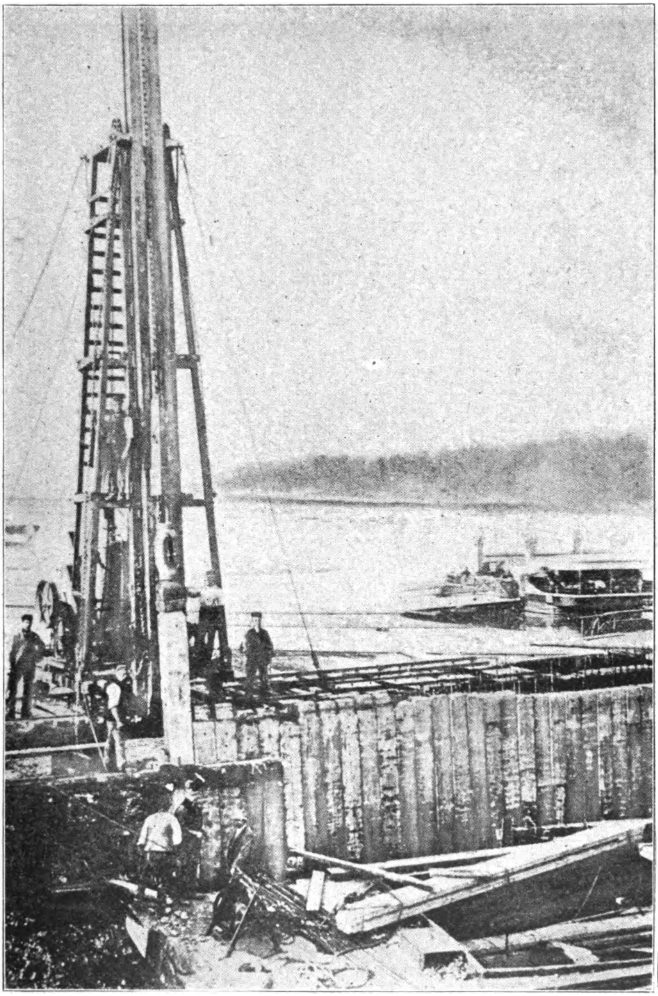


Fig. 58.—Driving of Reinforced Concrete Piles, using a 4,000 pound hammer. Section of piles, 8 by 16 inches; length; 40 feet.

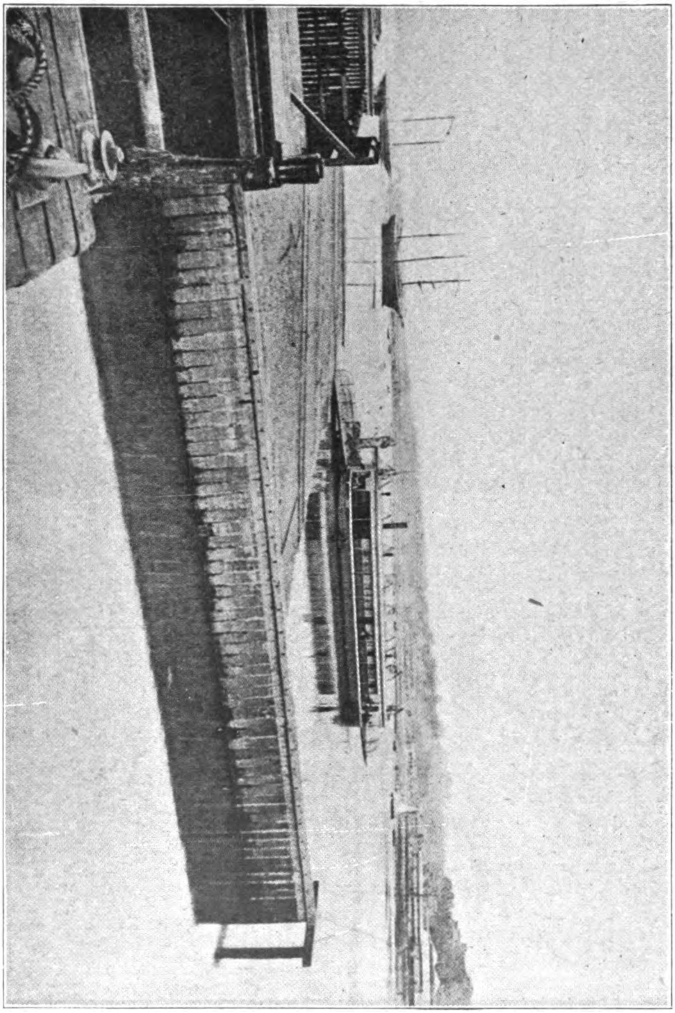


Fig. 59.—Retaining Bank, Southhampton, England, The piles are driven into 17 feet of hard sand and shingles.

frequent practice of driving wooden piles under the walls in order to reach a better and firmer stratum. The necessity for driving these piles to great depths largely increases the cost of the work and seriously impedes the operations without always giving satisfactory results.

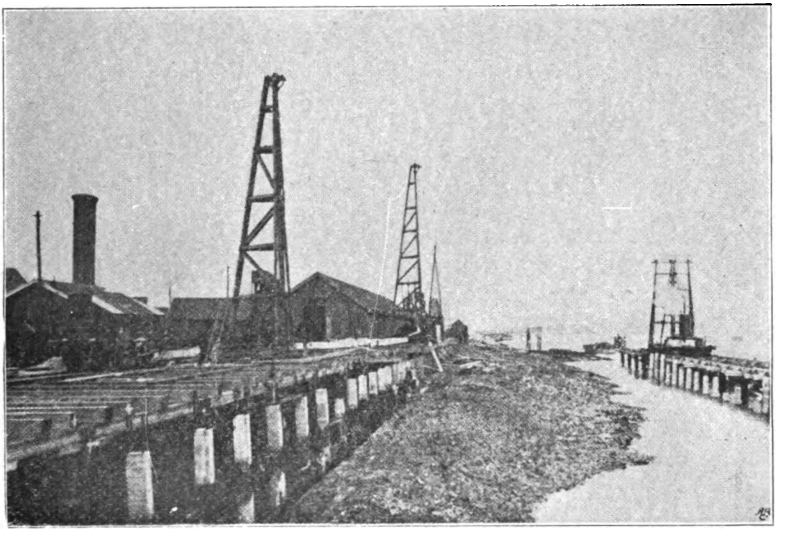


Fig. 60.—Barge-Quay and Jetty in course of construction.

Should, however, a masonry wall, as above described, remain stable as regards foundation, and the joints resist the effect of the waves, it nevertheless often remains exposed to the effects of the scouring of the ground. To remedy this latter evil it is customary to enclose the work by wooden sheet piles, but their exposed parts rapidly decay or are destroyed by other agencies.

The use of reinforced concrete piles and sheet piles obviates these evils. The following are the principle advantages claimed for these piles as applied to sea work: they can be manufactured in any practical length and section and they can be driven as a con-

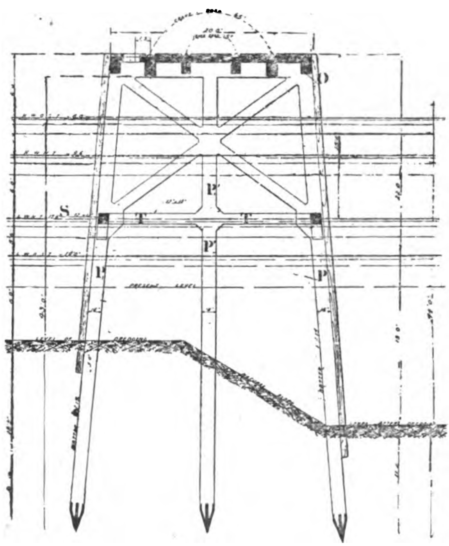


Fig. 61.—Cross-section of Jetty.

tinuous pile to great depths. Sheet piles form a water-tight barrier without a single horizontal joint, which can be calculated to resist any pressure that is brought to bear upon it. This water-tight wall is carried down to the firm stratum, thus preventing any disturbance that might take place below the base of an ordinary wall; once built its relative lightness is such that it does not add appreciably to the original density of the ground.

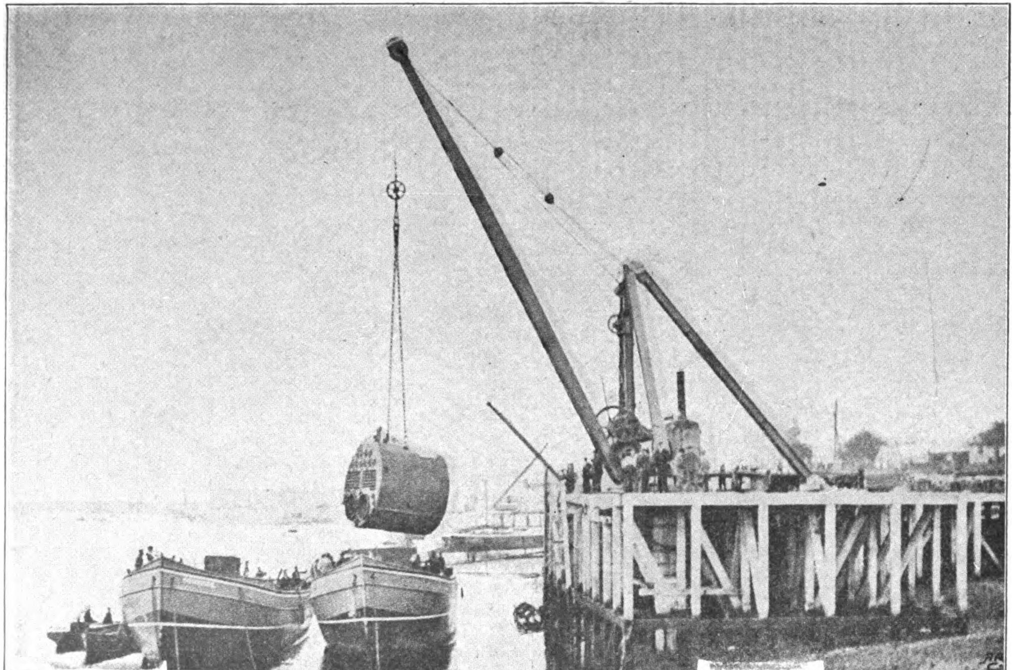


Fig. 62.—Woolston Jetty, designed for a live load of 1,600 pounds per square foot, and for supporting a 60 ton crane.

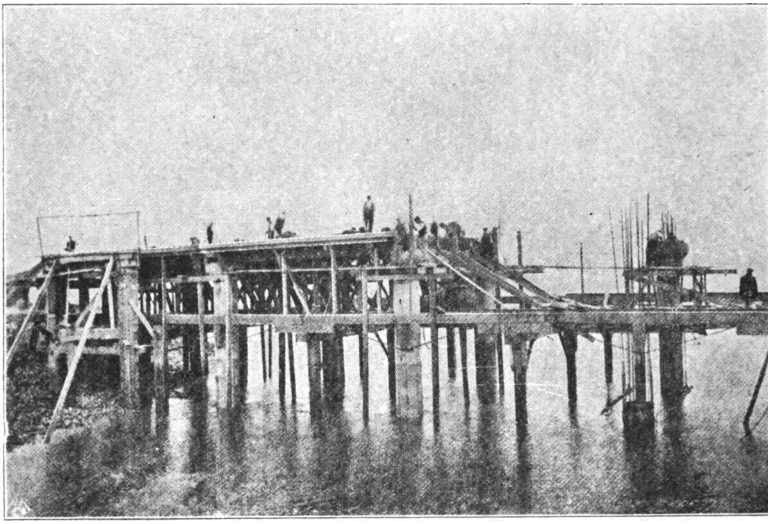


Fig. 63.—Dagenham Jetty in course of construction.

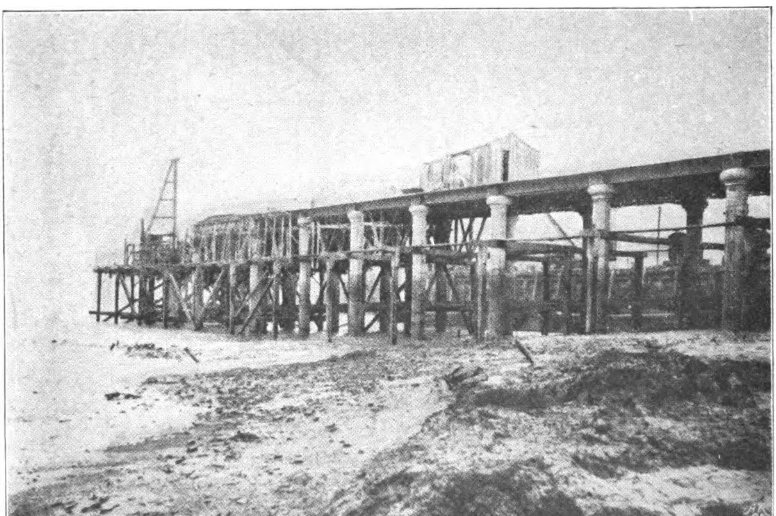


Fig. 64.—Dagenham Jetty in course of construction.

The piles used in jetty construction are braced by struts and covered by a reinforced concrete floor strong enough to carry the super-imposed loads, railroad tracks or cranes, which may be imposed upon them. It is clear that the cost of such a jetty must be very much lower than if built of stone or solid concrete.

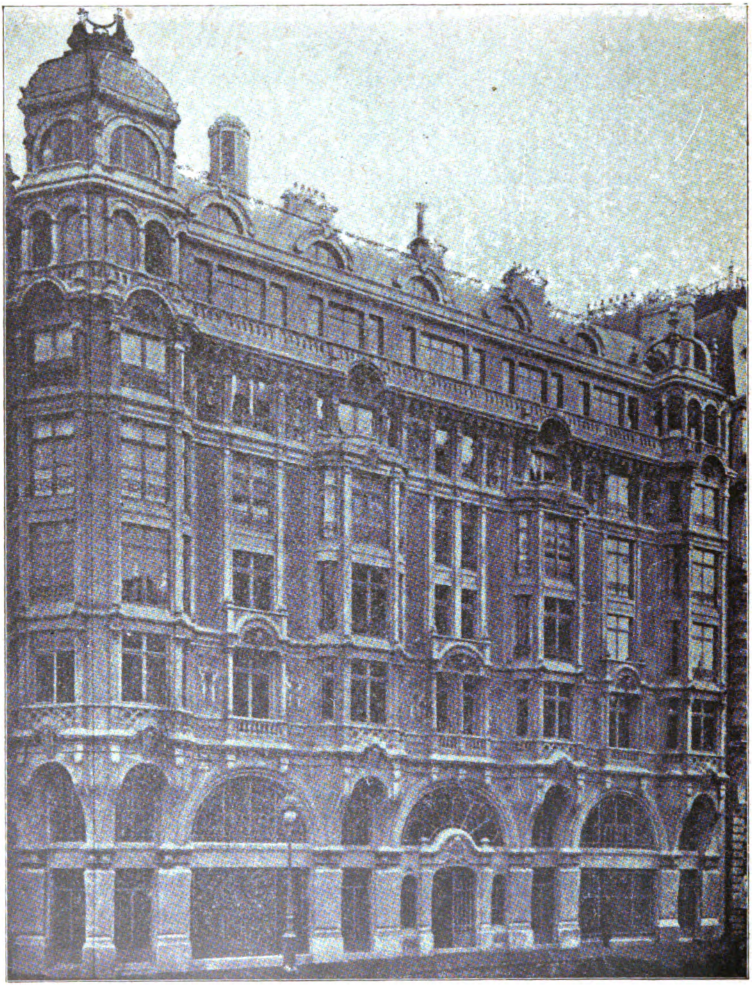


Fig. 66.— Apartment and Office Building, Paris, France.

CONSTRUCTION OF REINFORCED CONCRETE WALLS.

Reinforced concrete walls are seldom built solid in imitation of brick walls, where they have to support several floors. It is more economical to transmit the floor loads to reinforced concrete columns, which form

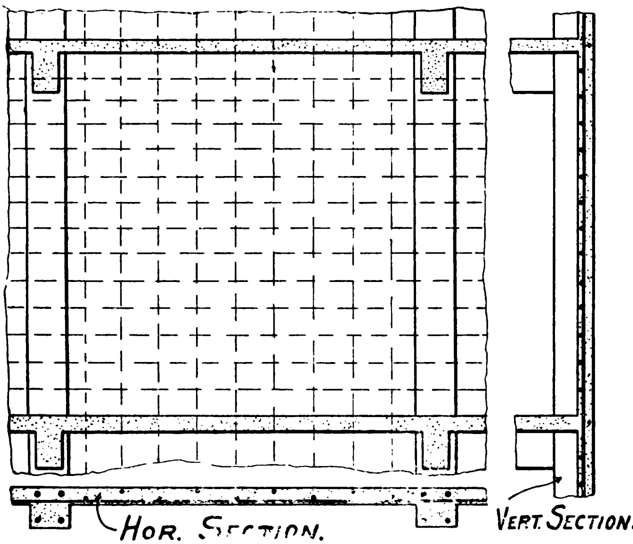


Fig. 65.—Reinforced Concrete Wall.

pilasters in the walls, and are therefore only curtain walls (see Fig. 65). These curtain walls are subject to very little stress; in outside walls they have to withstand the wind pressure, which is generally figured at

30 lbs. per sq. foot. To prevent cracking owing to the influence of change of temperature we have to make these walls three and one-half to four inches thick, and for the same reason they have to be reinforced by steel rods in both directions, which reinforcement is more than sufficient to take care of the wind stresses. These walls are of great importance for buildings in the business district of our large cities, where each front foot has a valuation running into many thousands of dollars; by adopting side walls 4 inches thick, one and one-half to two feet in width of building is easily saved. The same holds true for storage-houses which are often divided up by a large number of brick partition walls. These walls are also much lighter than brick walls, having a weight, in fact 1-3 to 1-4 of the latter, thus reducing the cost of foundation considerably, especially where pile driving is necessary. It is needless to point out that, by the use of concrete walls, we obtain a rigidity of the building, which cannot be had by any other construction.

Fig. 66 shows a highly ornamented reinforced concrete front wall; all ornaments are cast in place and monolithically connected with the wall which is 4 inches in the top story and increases to 7 inches in the first story.

This is by no means an easy and low priced contruction; only specially experienced workmen can do an acceptable job; and it is much easier to build up such a front of separate blocks of artificial stone.

If only a simple and neat front is required without being ornamental, a one inch cement finish is applied to the wall; this also is not an easy job and requires men well experienced in this class of work; for ex-

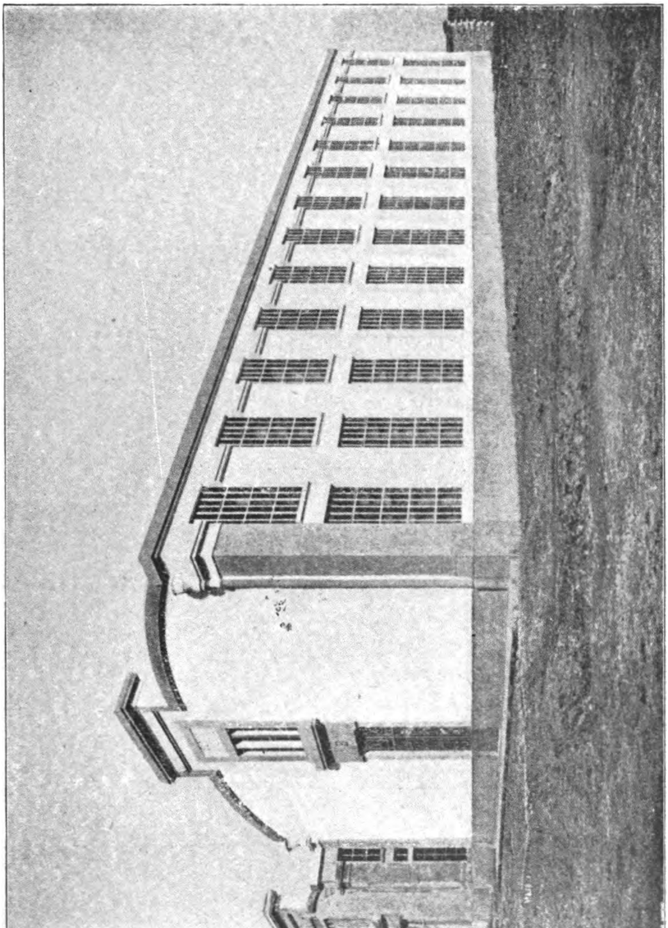


Fig. 67.—Fireproof Archive Building, Paris, France.

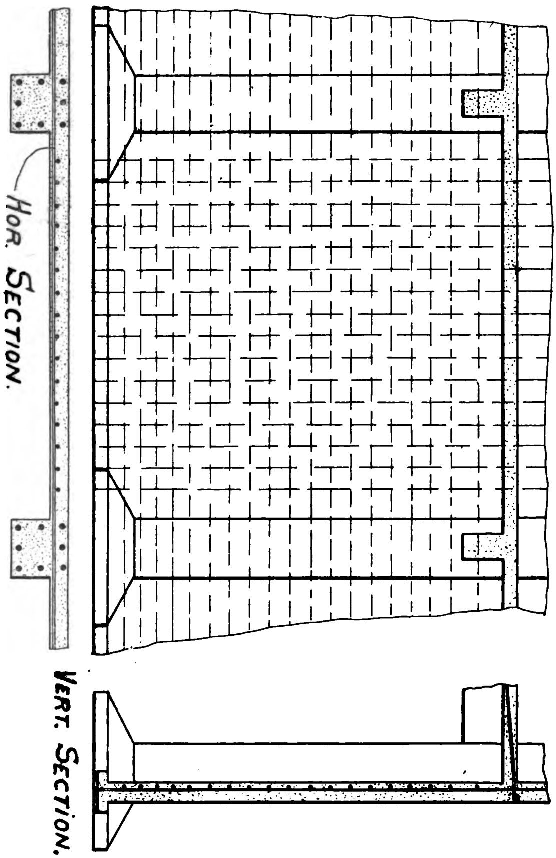


Fig. 68.—Reinforced Concrete Basement Walls.

ample, see Fig. 67. Sometimes the walls are finished by rough picking them, by hand, or pneumatic tools, a week or so after concreting. Fig. 68 shows the application of armored concrete to basement walls. These walls are required to withstand the horizontal pressure from the earth and from the load on the ground above near the wall. This horizontal pressure will rarely exceed an average of 300 pounds per square foot, for the depth of the basement in general use, and by inspecting the table given for floor slabs, it will be found that it is rarely necessary to make these walls more than 6 inches thick, if the pilasters in the walls are spaced 10 to 15 feet. It is clear that these pilasters, which are often the outside wall columns, are subjected to bending, and must be designed accordingly.

REINFORCED CONCRETE STAIRS.

One of the most essential features of a permanent building is a substantial, fireproof stairway. For this purpose there is no material which has so many good properties as reinforced concrete. Compared with steel stairs, reinforced concrete stairs has numerous advantages, as follows:

First, the cost can be reduced to one-half of that of steel construction, with decided improvement in appearance.

Second, they are absolutely fireproof, as far as any known material can be made to attain this end.

Third, reinforced concrete, applied to stairs, can be molded into any shape, and can be given either a plain or elaborate finish.

Fourth, as seen from below, no unsightly structural steel members are exposed, the soffit of concrete stairs

Fifth, the risers, treads, stringers and soffit can be cov-presenting a clean and even surface ready for plaster-ing.
ered with marble, scagliola, cement, granolithic, mo-

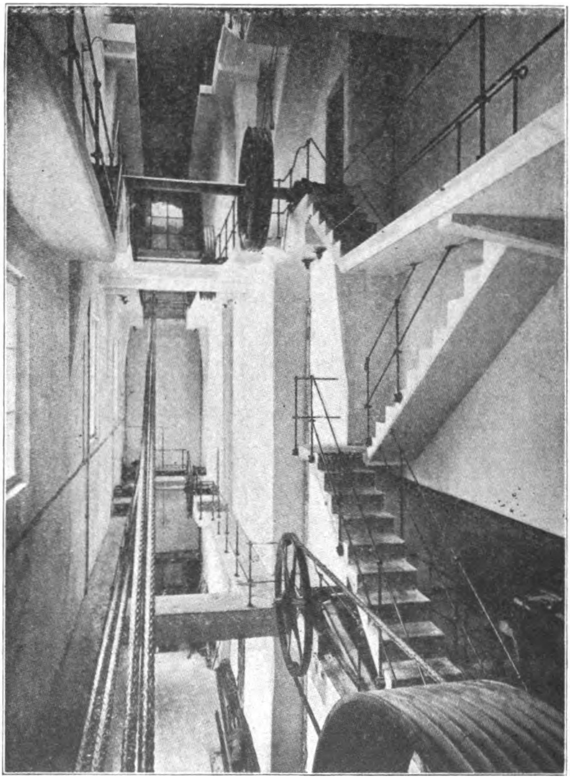


Fig. 69.—Stairs, Cantilever Galleries and Cable Drive in a Spinning Mill.

saic or wood finish, and in fact concrete stairs may be treated to any design suitable to harmonize with the surroundings.

At the ordinary market price of cut and polished marble it is possible to build a concrete stairway covered with slabs of marble at less cost than steel stairs with cast iron treads and rises.

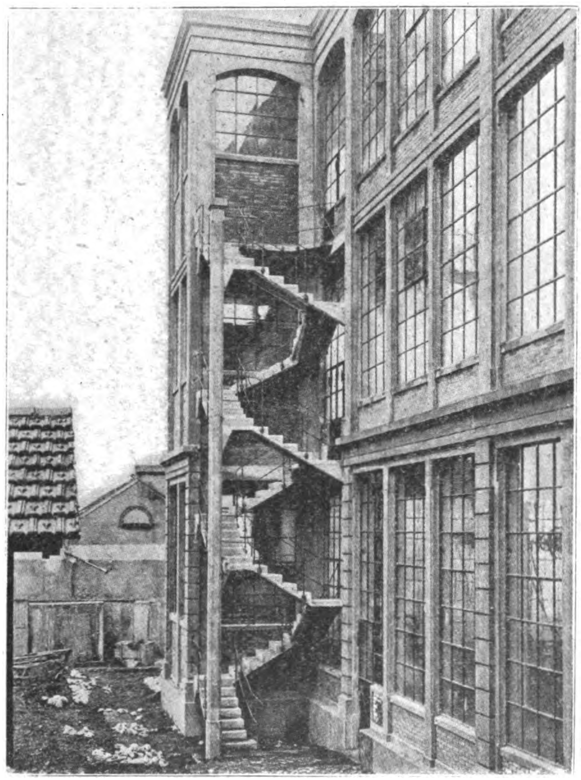


Fig. 70.—Fire Escape, Spinning Mill. "La Cite," Strassburg.

Reinforced concrete stairs usually consist of horizontal floor slabs in the landings, which are connected to the inclined slabs of the flights, and a number of girders supporting these landings and flights.

The risers and treads are monolithically connected with the slabs, both being concreted simultaneously. Where the free spans do not exceed ten feet or thereabouts, the stairs can be constructed without any other visible

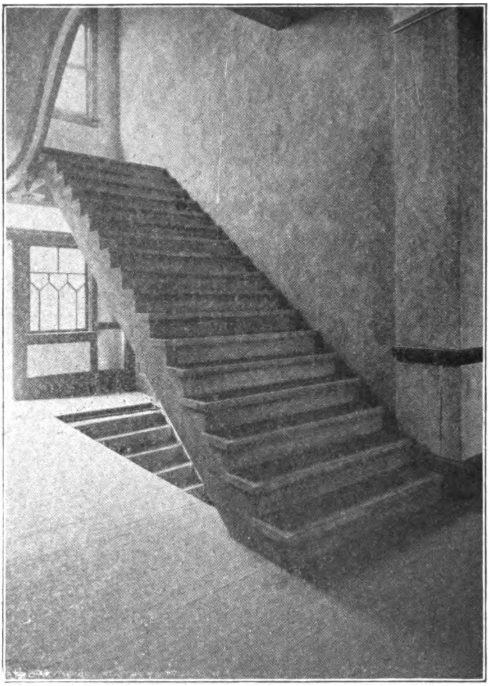


Fig. 71.—Staircase, Salvation Army Building, Cleveland, O.

support than the slabs. For larger spans girders must be provided to support landings, and stringers must likewise be used and treated as girders.

The stringers may be built either as open or closed stringer; two to four inches thick will be ample for ordinary spans, and of any depth to meet the architectural requirements. Figs. 69 and 70 show stairs

built up of concrete slabs without stringers, while Figs. 71 and 74 show stairs of open stringer construction, and Figure 72 shows a closed stringer type.

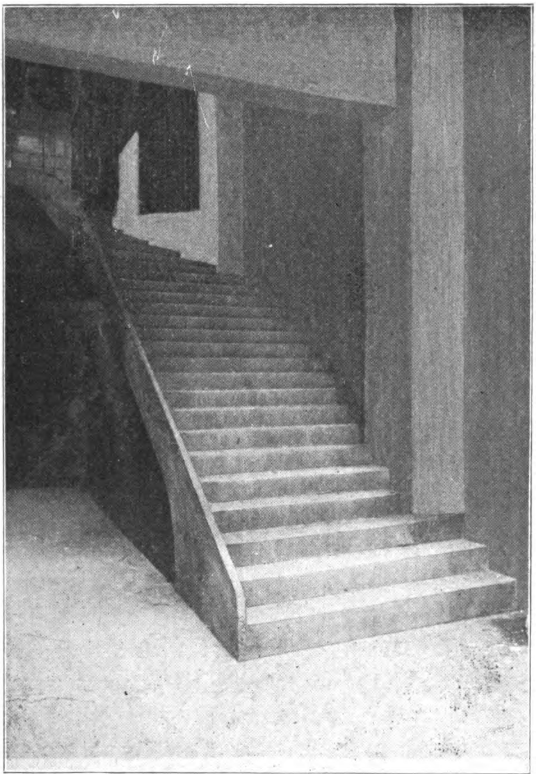


Fig. 72.—Staircase, Ingall's Building, Cincinnati, O.

These stairs can be built to conform to any geomatrical form used in existing staircase construction of other material. For example, for winding and spiral stairs, as shown in Fig. 98.

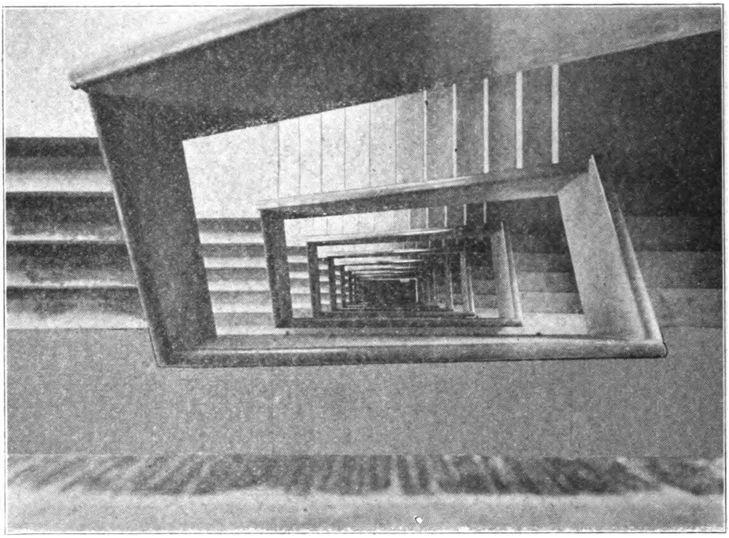


Fig. 73.—Looking down 10 Flights of Stairs, Power Building, Cincinnati, O.

The cheaper class of concrete stairs may be given a cement or granolithic finish, with a nosing in exact imitation of cut stone steps. These stairs have been adopted in numerous school houses and public buildings in England and France. Where the stairs are subject to considerable travel, the treads are sometimes inlaid with cubes of lead, rubber or wood, two to three inches apart, to give a more secure footing, as the surface otherwise becomes polished.

The material for railings and newel posts may be cast or wrought iron or other metal, wood, cut stone or concrete. The railings are fastened to the top of the stringers or treads by means of expansion bolts, screwed into holes, which are provided in the con-

struction of the stairs, or by bolts which are imbedded in the triangular face of the steps, where there are no stringers, or, as it is often the case, the railing

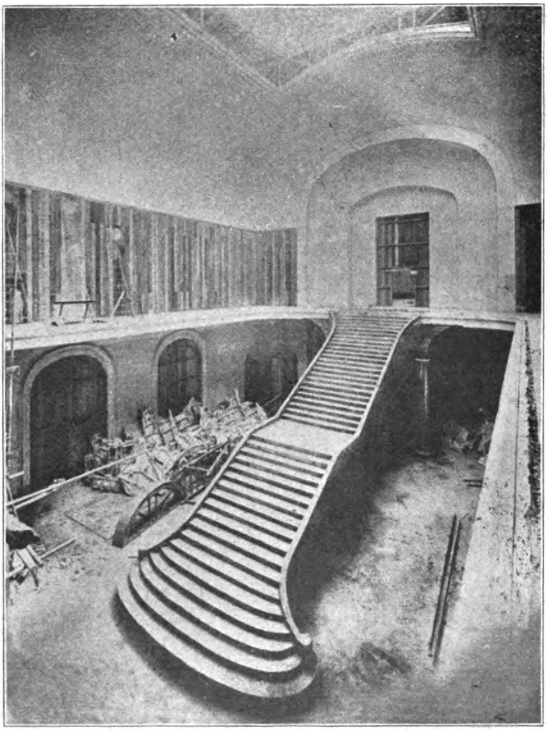


Fig. 74.—Concrete Staircase, Cantilever Galleries and Ceiling in a Department Store.

is only fastened to the newel posts. For the latter, sockets are left in the landings and lower and upper treads, as required, in identical manner as in wood construction.

REINFORCED CONCRETE SKELETON BUILDINGS

Reinforced concrete skeleton building construction will scon come into universal use for high office buildings, hotels, ware-houses, etc., on account of the great economy this type of construction offers to the public

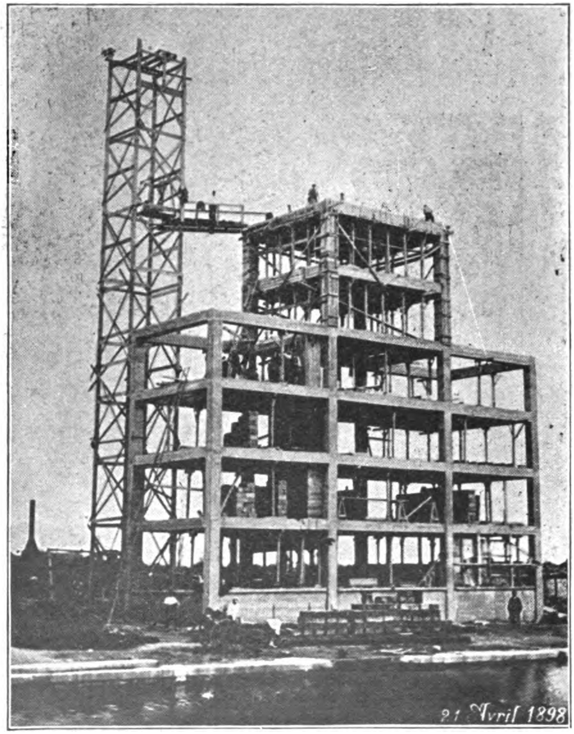


Fig. 75.—Reinforced Concrete Skeleton of a Flour Mill. Columns, 27 feet on centers.

compared with steel construction, even meeting the competition of wood construction. We understand by skeleton construction, a frame composed of columns

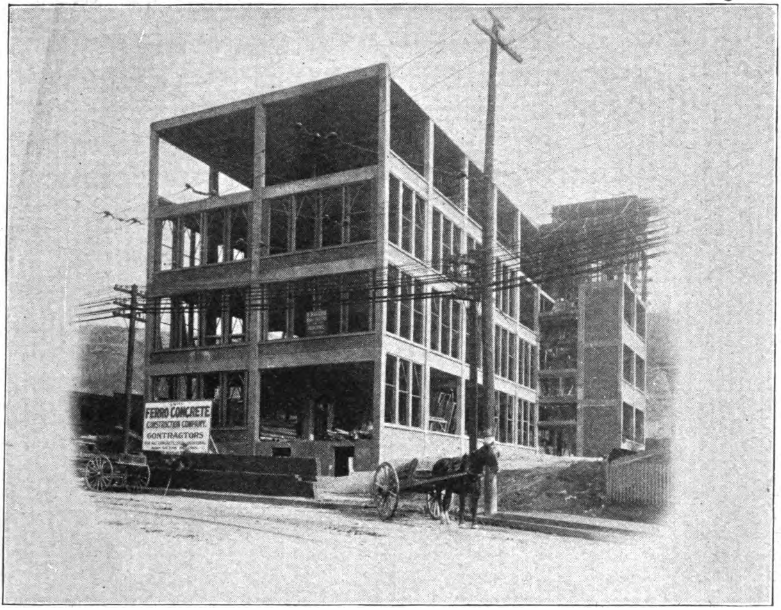


Fig. 76.—MacDonald & Kiley's Shoe Factory, Cincinnati, O. Reinforced concrete skeleton construction. 8 inch brick fillings.

and girders supporting all the outside walls, from story to story, making it possible to reduce the thickness of the walls to a minimum in each story. This arrangement gives increased floor space, and reduces the weight of the walls as well as the cost of foundation.

The outside walls being reduced to curtain walls, their thickness in high office and hotel buildings is dependent on the architectural treatment, though usually 12 inches thick, while in ware-houses and factories, 8 inch walls are sufficient. In hotel and office buildings

the columns and lintels are always lined with stone, brick or terra cotta and for this purpose anchors are imbedded in the concrete columns and 3 1-2 x 2 1-2 x 1-4 inch angles are bolted to the lintels, as shown in Fig. 77. In ware-houses and factories the columns and girders can be left exposed to view, and finished

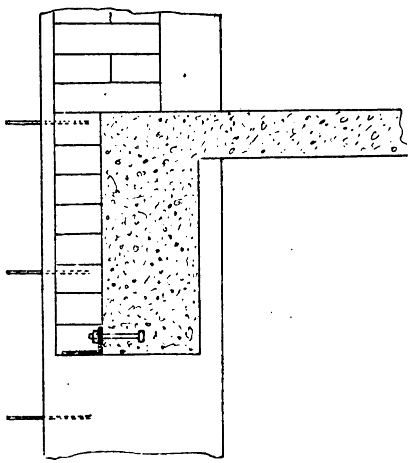


Fig. 77.—Detail showing Brick Anchoring of Brick Facing to Concrete Lintels and Columns.

by rough picking or by cement mortar in imitation of cut stone columns and lintels. The curtain walls are erected on the upper surface of the lower lintels and extend from column to column, are carried up to the lower surface of the upper lintel, thus covering the entire panel except where openings for windows are required. Brick curtain walls can be replaced with economy by walls of hollow concrete blocks, and we thus obtain an all-concrete construction. There are, however, only very few concrete blocks which we have found satisfactory; most of those on the market rapid-

ly absorb water and should not be used. A very satisfactory block is made by Mr. Charles W. Stevens, of Harvey, Ill.; it is also claimed that the blocks manufactured by hydraulic pressure do not absorb water; there may be other satisfactory blocks on the market, unknown to the writer.

Four inch reinforced concrete walls can also be used but they are more expensive than 8 inch brick or concrete block walls. In an all-concrete building all the columns, footing of columns, basement walls (see Fig. 68), girders, beams, lintels, floors, roofs and stairs are built of reinforced concrete, while the walls may be of reinforced concrete or concrete blocks.

Tile or reinforced plaster partitions are less expensive than armored concrete partitions. The latter, however, can withstand the action of fire, impacts from streams of water or falling objects much better than the former, and should be adopted, where it is of great importance to prevent the spread of fire from one part of a building to the other. Stair case and elevator walls, as well as fire-proof vaults should be built of concrete instead of hollow brick, as heretofore universally used. We find in nearly every great fire, that the brick walls crack and fall; it is, however, safe to say that a vault, built from the foundations up of 6 to 8 inch concrete walls, heavily reinforced by steel rods, will withstand the severest conflagration and remain intact even where the surrounding walls of the building collapse and cover the vault with the debris.

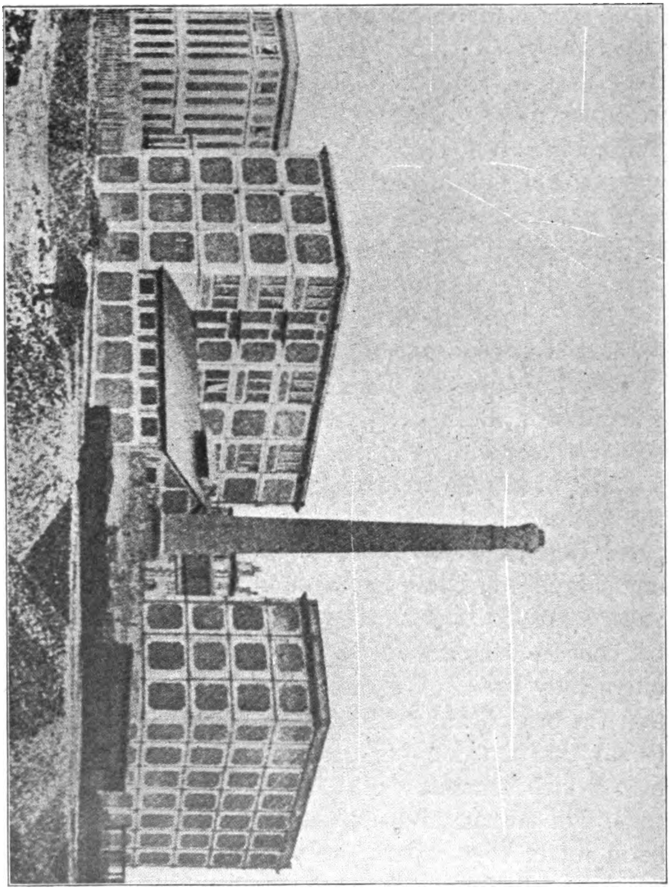


Fig. 78.—Flour-mill, Grain Elevator and Smoke Stack in Brest, France. The entire group of buildings is of concrete construction.

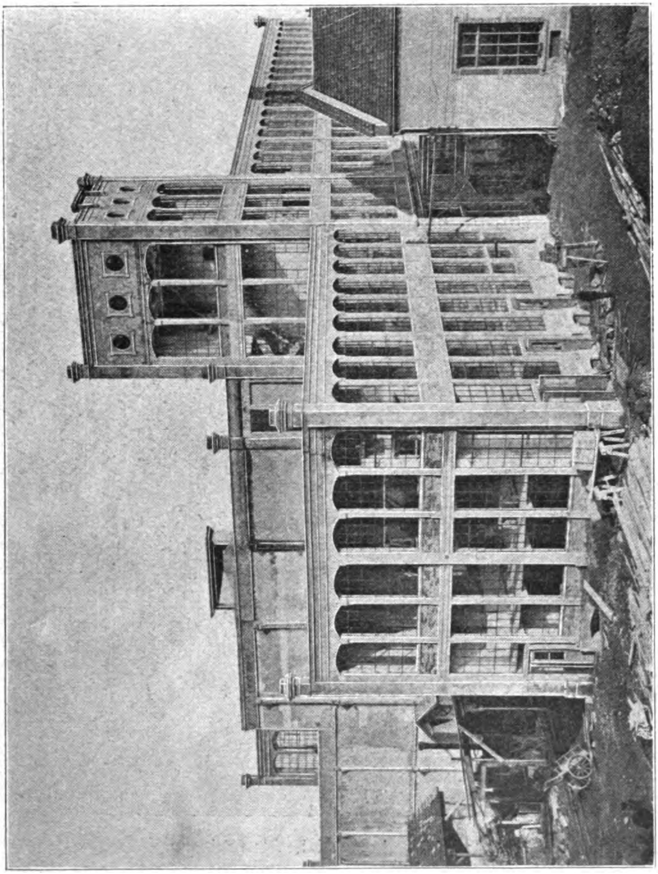


Fig. 79.—Cotton Spinning Mill, Strassburg, Alsace.

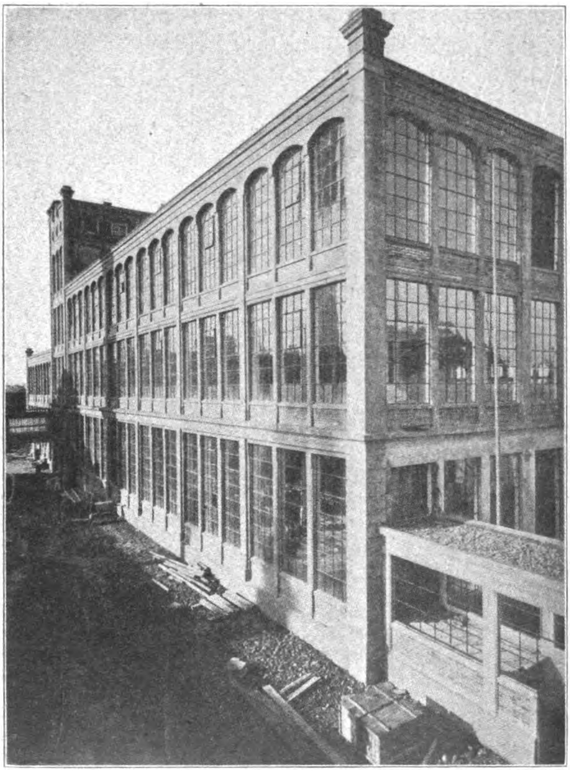


Fig. 80.—Cotton Spinning Mill, Strassburg, Alsace.

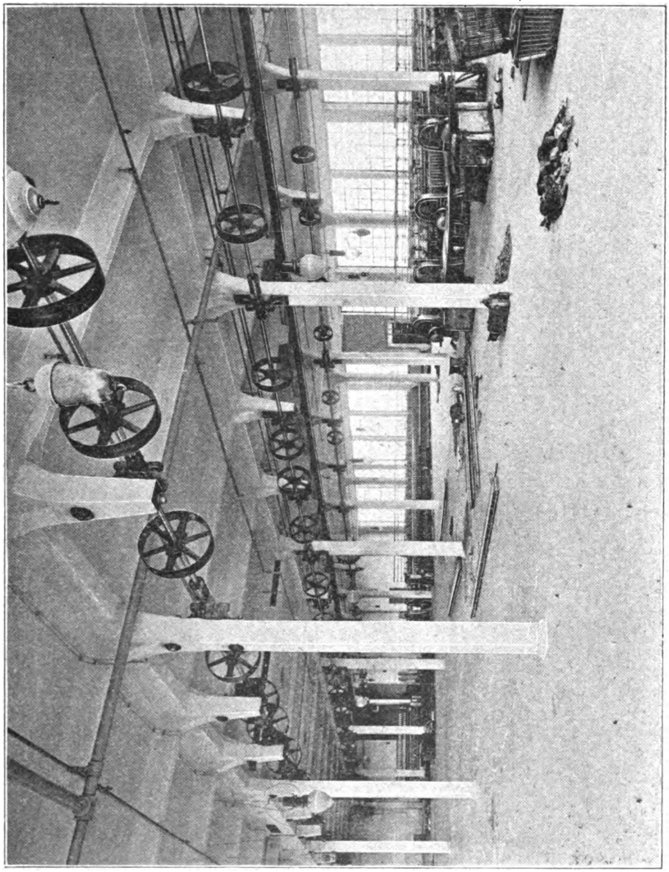


Fig. 81.—Interior of Cotton Spinning Mill, Strassburg, Alace. Line of shafting is supported by reinforced concrete hangers.

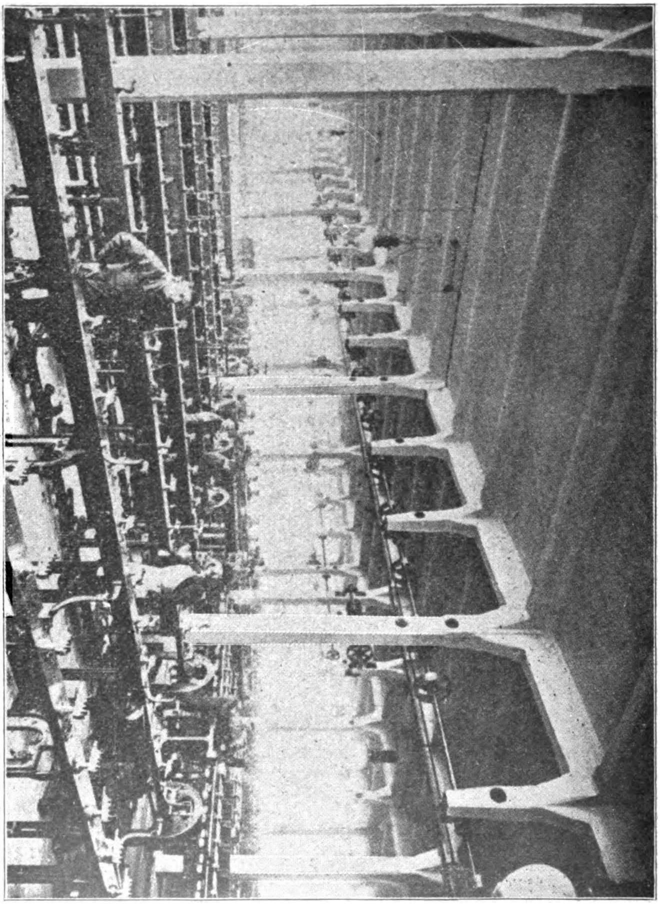


Fig. 82.—Interior of Cotton Spinning Mill, Strassburg, Alace.

Fig. 78 shows a flour mill in Brest, France, built entirely of armored concrete; the building site contained quick sand to a considerable depth and concrete pile foundations were resorted to as the most feasible method to obtain a suitable foundation; nevertheless it settled considerably, as much as 12 to 18 inches in parts, causing several beams and floor slabs to crack; however, it safely carries the heavy live loads imposed by the use of the building, and this can only be ascribed to the use of stirrups in the girders.

Figs. 79 to 82 show a cotton spinning mill in Strassburg, Alsace, constructed entirely of armored concrete. This building is 140x140 feet and three stories high. The columns are 24 feet on centres in both directions and serve as supports for lines of shaftings.

Figs. 81 and 82 show a novelty in mill construction, the line of shaftings being supported between the columns by reinforced concrete hangers, which have proven to be much more rigid than cast iron hangers. It must be noticed that this building is unusually well lighted, which could not have been attained by any other form of fireproof construction.

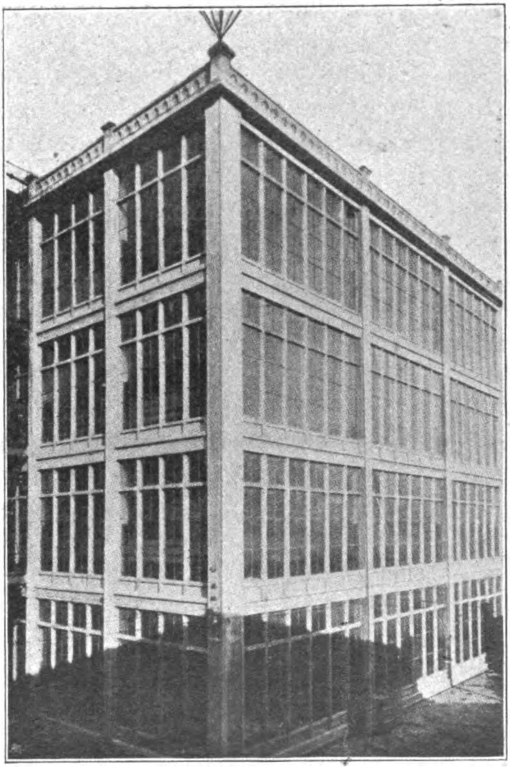


Fig. 83.—Cotton Spinning Mill, Lille, France.

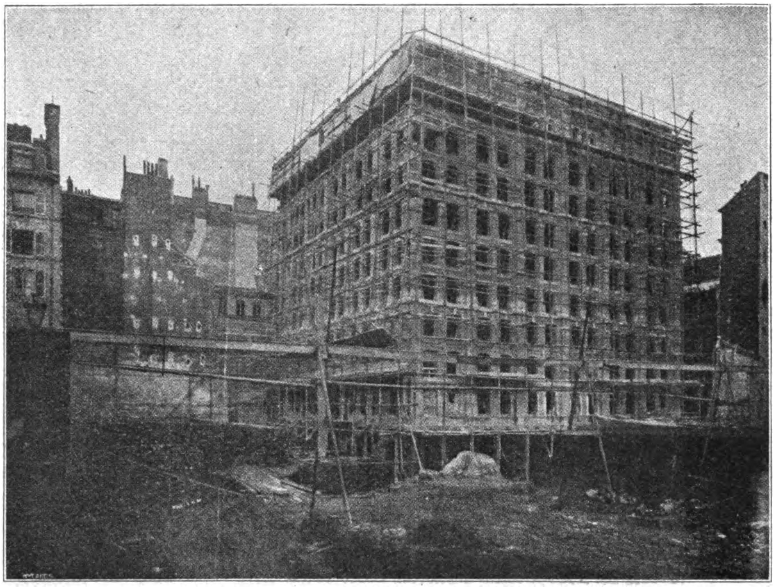


Fig. 84.—Eleven Story Audit Office, Paris, France.

Fig. 84 shows the 11-story Audit office of the French government, having a reinforced concrete skeleton. All fireproof vaults in this building are of concrete; since this modern construction has been adopted by a government of one of the first civilized countries for such an important structure, it must have proved first class in every respect, and should amply meet the requirements of private buildings.

The highest reinforced concrete skeleton building is the 16-story Ingalls' building, in Cincinnati, O., erected

Fig. 85.—Ingall's Building, Cincinnati, O.

in 1903. It is 50x100 feet and 210 feet high above the curb line. This building was very rapidly erected, averaging eleven days per story. Each floor formed a perfect roof, under which all plastering, piping, wiring and interior finish was carried on, whereby much time was saved over other methods of construction The idea of constructing a high office building in armored concrete was considered such a novelty in this country that the Cincinnati Inspector of Buildings withheld the building permit for many months.

A wasteful amount of steel and concrete was eventually used in the construction, to overcome the objections of the city authorities; and the Ingalls' building is probably the strongest high building ever erected in this country; with all this waste of material a notable economy over the ordinary type of steel skeleton construction was obtained, and the time of erection was also considerably reduced. Messrs. Elzner & Anderson were the architects, W. H. Ellis & Co., the general contractors, and the Ferro-Concrete Co., of Cincinnati, the contractors for the reinforced concrete work.

From every point of view armored concrete buildings are superior to those of any other type. They are monolithic; settlement of the ground is properly transferred and equalized by their enormous rigidity; they practically consist of one material and variation of temperature cannot produce unsightly cracks; they become stronger with age, concrete forming an artificial stone better than the best stone which ever came out of a quarry. Considering, moreover, the facility with which the material can be procured, so that a few months are needed to erect the largest building, together with the surprisingly low cost, it must be evident that the time of steel skeleton buildings with all

their flimsy lug and bracket connections, their insufficiently protected columns and their high cost, is rapidly passing and must shortly give way to a far superior type, namely, armored concrete construction.

The reader undoubtedly desires to know how the cost of this modern type of construction compares with that of skeleton steel construction. It depends, of course, on the cost of the materials, cement, sand, crushed stone and steel rods, varying in different localities. Generally speaking, an all-concrete factory or ware-house can be built for from 7 to 8 cents a cubic foot, based upon the cubic contents of the building, and does not include windows, doors or interior finish.

For hotel and office buildings, the concrete skeleton including all foundations, floors, roof, basement walls and stairs can be built for from 6 to 7 cents a cubic foot, which figures will be found to be from 25 to 40 per cent lower than for steel construction, depending upon the price of structural steel.

VIBRATIONS IN ARMORED CONCRETE STRUCTURES.

The monolithic character of an armored concrete buildings is evidence that vibrations produced by impacts, or working machinery, will be much smaller than in any other class of buildings. Any particular point of the structure, which is affected by an impulse, brings into oscillation every part around it, vibrating a large mass of great rigidity; therefore, the oscillations must be far less than in steel or wood structures, where the beams and arches are only loosely connected, and can be set in vibration independent of other parts of the building. We have seen how small the deflection

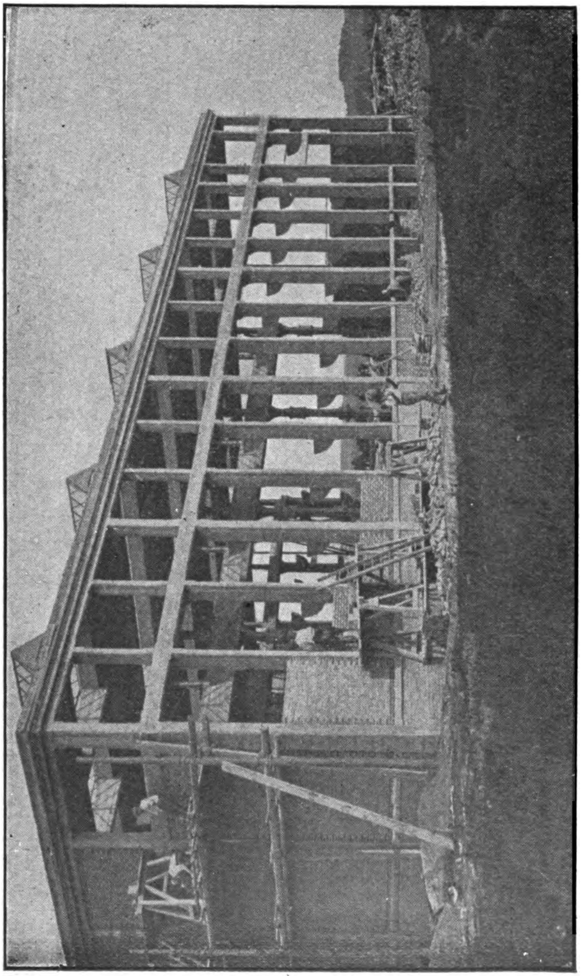


Fig. 86.—Factory Building. Reinforced Concrete Skeleton with Brick Filling.

Maximum Elastic Deflection in Inches of Sym-

with an equally distributed load (W) and strained to 16,000 $.01655 \frac{L^2}{d}$ when L=span in feet, d, depth of girders in

Depth of Girder in Inches.	SPAN IN FEET.										
	4	6	8	10	12	14	16	18	20	22	24
4	.0661	.149	.265	.414	.595	.810	1.06				
5	.0529	.119	.212	.331	.476	.648	.845	1.07	1.32		
6	.0441	.0993	.177	.276	.397	.540	.707	.891	1.10	1.33	
7	.0379	.0851	.152	.237	.340	.465	.606	.766	.946	1.14	1.36
8	.0331	.074	.132	.207	.298	.405	.530	.670	.829	1.000	1.19
9	.0295	.0662	.118	.184	.246	.361	.471	.596	.737	.890	1.06
10		.060	.106	.165	.240	.326	.425	.540	.667	.807	.960
11		.054	.096	.150	.216	.295	.385	.486	.600	.725	.862
12		.050	.088	.138	.198	.270	.353	.447	.550	.668	.781
13		.046	.081	.127	1.84	.250	.325	.412	.510	.617	.732
14			.075	.118	.170	.232	.302	.383	.472	.572	.680
15			.070	.110	.159	.216	.282	.357	.440	.530	.632
16			.066	.104	.149	.203	.265	.335	.413	.500	.596
17			.062	.097	.140	.191	.250	.315	.390	.471	.560
18			.059	.092	.132	.180	.235	.297	.368	.445	.530
19			.056	.087	.126	.171	.223	.282	.349	.422	.501
20			.053	.083	.119	.162	.212	.267	.331	.400	.477
21				.079	.114	.155	.202	.255	.315	.381	.454
22				.075	.108	.147	.192	.244	.300	.365	.432
24				.069	.100	.135	.176	.223	.276	.335	.396
26				.064	.092	.125	.162	.206	.255	.309	.365
28				.059	.085	.116	.152	.191	.236	.286	.340
30				.055	.080	.108	.141	.179	.221	.267	.318
35					.068	.093	.122	.154	.190	.230	.274
40						.081	.106	.134	.165	.200	.238
45									.147	.178	.211
50											.190
55											
60											

Deflections at right of heavy broken will cause plaster
For a concentrated load in center of span reduce figures

For any other fibre stress, 13,000 lbs., for example

metrical, Freely Supported Steel Girders.

lbs- per square inch, obtained by the formula $D = \frac{5}{384} \frac{Wl^3}{EI} =$

inches.

SPAN IN FEET.											Depth of Girder in Inches.
26	28	30	32	34	36	38	40	45	50	60	
											4
											5
											6
											7
1.40											8
1.24	1.44										9
1.12	1.30										10
1.02	1.18	1.35									11
.930	1.08	1.24	1.40								12
.860	1.00	1.14	1.30								13
.800	.925	1.06	1.20	1.36							14
.741	.863	.990	1.12	1.27							15
.700	.810	.930	1.06	1.19	1.34						16
.658	.762	.876	1.00	1.12	1.26						17
.621	.720	.829	.940	1.06	1.19						18
.589	.682	.784	.890	1.00	1.13	1.26					19
.560	.650	.745	.845	.950	1.07	1.19	1.32				20
.531	.620	.710	.805	.905	1.02	1.14	1.26	1.60			21
.508	.590	.677	.770	.865	.970	1.08	1.20	1.53	1.88		22
.467	.540	.620	.705	.792	.890	1.000	1.10	1.40	1.72	3.50	24
.430	.500	.572	.650	.730	.820	.920	1.02	1.29	1.59	2.25	26
4.00	.463	.531	.602	.680	.765	.850	.945	1.20	1.48	2.12	28
.363	.432	.498	.563	.635	.715	.800	.882	1.12	1.38	1.99	30
.320	.375	.429	.485	.550	.615	.685	.760	.960	1.18	1.70	35
.280	.325	.362	.422	.476	.537	.600	.661	.838	1.03	1.49	40
.248	.287	.330	.376	.422	.477	.530	.590	.745	.920	1.32	45
.223	.260	.298	.337	.380	.430	.480	.530	.670	.826	1.19	50
.204	.237	.271	.307	.348	.390	.435	.481	.610	.752	1.08	55
		.248	.281	.317	.355	.397	.440	.558	.688	.99	60

to crack.
by 1-5.

multiply above figures by $\frac{13,000}{16,000}$.

of armored concrete girders is under static loads and in comparing this deflection with the deflection given in the accompanying table for steel beams, it will be found they are often only 1-5 to 1-10 of the latter.

We cite a very interesting comparative experiment made at two stations of the Orleans R. R. in Paris.

A Amr. concrete floor, figured to carry a machinery load of 280 pounds per square foot, of a span of about 16 feet, was subjected, for a length of 17 feet, to a load of 420 pounds per square foot. The maximum deflection was 1-8 inch, without any permanent set. In order

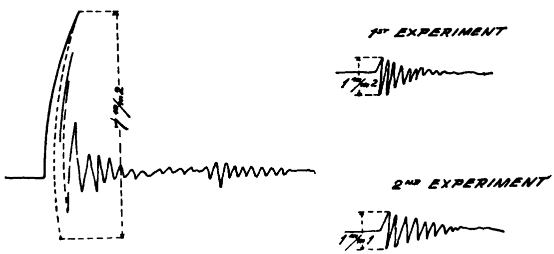


Fig. 87.—Vibration Diagrams.

to compare the resistance of this floor to shocks with that of steel girder floors, this floor and a floor of the Quay d'Orsay station, built for the same purpose and of the same span, but consisting of I beams and brick arches, were subjected to the impact of falling weights. The dead weight of the Amr. concrete floor was 60 pounds per square foot, that of the other, 96 pounds per square foot. A weight of 110 pounds, falling from a height of 6 1-2 feet, produced in the steel and brick floor, vibrations of an amplitude of 5-32 inches, lasting two seconds, while a weight of 220 pounds, falling from a height of 13 feet on the concrete floor, caused a maximum vibration of only 1-32 of an inch,

lasting 5-7 of a second. Thus, twice the weight falling twice the height, caused only one-fifth of the deflection, with vibrations lasting only a third of the time (See Fig. 87).

This is of great advantage in bridges, and especially in factory buildings, not only because the lives of such structures are threatened by vibration, but also because absence of vibration preserves the tools and makes better work possible.

FIREPROOF QUALITIES OF REINFORCED CONCRETE.

Concrete is the best fireproof material for building purposes. This was demonstrated over ten years ago by comparative tests by the fire departments of the cities of Vienna and Berlin; more recently by the fire tests conducted by the British Fire Prevention Committee, and by the very careful and severe tests on a score or more reinforced concrete floors by the building department of the city of New York.

In the latter city for each test a house 10x14 feet in the clear, and about 12 feet high, was built and covered by the concrete floor to be tested. The interior of the house was filled with coal and wood, and for five hours a temperature of over 2,000 degrees Fahrenheit was maintained, and then a stream of water from the nozzle of a steam fire engine was directed for a few minutes on the ceiling. All the floors stood the tests remarkably well, supported the uniformly distributed load of 150 lbs. per square foot without undue deflection, and with the exception of a few fine hair cracks, which disappeared after cooling off, no damage whatever was done to the floors. On the other hand we know unprotected steel behaves worse in a severe fire

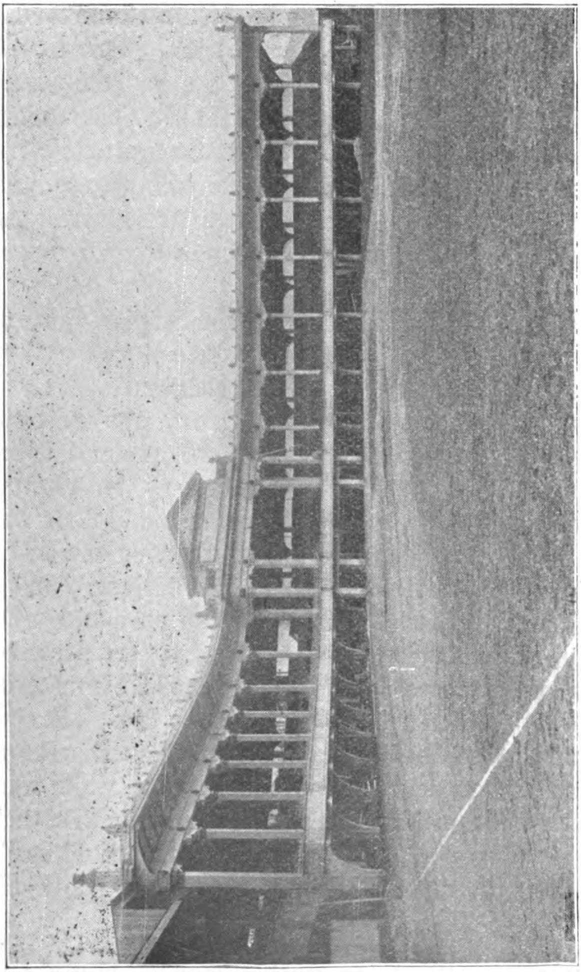


Fig. 88.—Grand Stand at Baseball Grounds, Cincinnati, O. Entirely of armored concrete; built by the Ferro-Concrete Construction Co.

than heavy mill construction. It twists and warps into various shapes after a temperature of 1,000 degrees Fahrenheit is reached. This was demonstrated by the fire at the works of the Pacific Borax Com pany's plant at Bayonne, N. J., in 1902. Part of the plant was of all-concrete construction, and the annex was of unprotected steel construction. The annex was a distorted mass of iron after the fire, while the concrete building stood the trial exceedingly well, requiring only plastering to restore it to first class order. The heat in the latter was great enough to melt copper and cast iron.

We also cite a fire test made by the Belgian Government and Mr. Hennebique on a two-story pavilion erected for this purpose at Ghent, Belgium.

This pavilion, measuring 20x15 feet, was built entirely of ferro-concrete, and the windows and doors were provided with Siemens wire glass. In all, two tests were made. In the first test the second floor was loaded with 300 pounds per square foot, or one and a half times the load for which it was designed, and a deflection of 1-3,000 of the span was produced. On the 9th of September, about 220 cubic feet of wood and coal were placed in the lower room. This material was sprinkled with petroleum and set on fire. The conflagration lasted one hour, and produced a temperature of about 1,3000 degrees Fahrenheit. The walls were red hot on the inside; yet, notwithstanding that their thickness was only 4 3-4 inches, the hand could easily be held on the outside without experiencing any discomfort.

The temperature of the second floor increased only 4 degrees, which means that no mercantile product whatsoever would have suffered damage. The deflec-

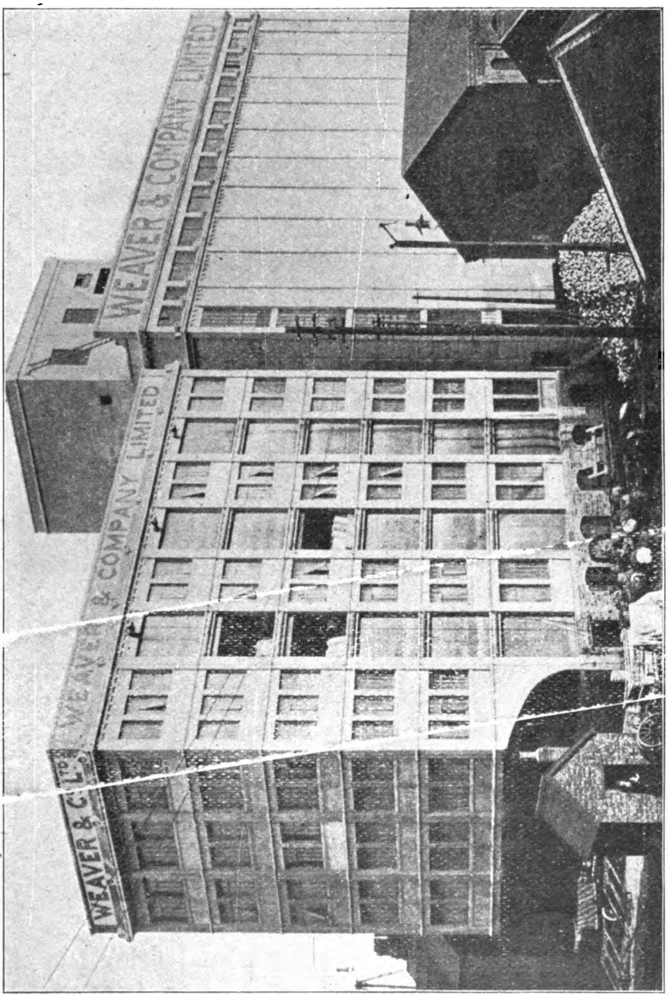


Fig. 89.—Flour Mill and Grain Elevator, Swansea, England. Part of the mill is supported by cantilever girders in each story.

tion of the floor increased to 6-10 of an inch, but two hours after the extinction of the fire, was diminished by half an inch, so that under a very heavy load the permanent deflection resulting from the fire was scarcely perceptible.

In order to prove that an armored concrete floor, which had been subjected to fire, was still capable of bearing the same loads as before, Mr. Hennebique made a new test on the 28th of September; this time loading the floor with 400 pounds per square foot, or double its figured load. When the 300 pound mark was reached the deflection was found to be precisely the same as before the first fire test. At 400 pounds per square foot the deflection was only 1-8 of an inch.

The lower room was completely filled with wood and coal, the upper room partially filled with the same materials, and the roof was loaded with 200 pounds per square foot. At six minutes past four the fire was lighted on both piles and lasted until half past six. The fire played so fiercely against the sides and ceiling that the plastering of the latter was calcined, and the wire glass of the windows and doors melted.

The building was momentarily forced out of shape (expanded), but showed no cracks and only very fine fissures, which in no case permitted the hot air to escape. Again the contact of the hand to the outside of the walls could easily be endured. The deflection of the second floor reached a maximum of 3-4 inch at 20 minutes to six; after this time no further increase could be observed.

At half past six, when, after continual firing, no change in the state of the building could be detected, the commission agreed to extinguish the fire, which was done by directing a stream of water from a hose

against the walls and ceiling and against the hot coal.

When, on the following day, the fire authorities examined the building, it was found that the conflagration had not injured the general structure in any way. There was no permanent set in the floors and the few fissures caused by the expansion were completely closed. A series of pyrometers indicated a temperature of 2,200 degrees Fahrenheit.

Lime kilns, constructed entirely of concrete, have endured for years a temperature of 2,200 to 2,500 degrees Fahrenheit.

All these fire tests are of little importance in comparison with the fire tests which steel skeleton buildings with terra cotta fire-proofing, and concrete steel skeletons had to withstand in the terrible Baltimore conflagration on the 7th and 8th of February, 1904, which continued for 27 hours, and destroyed 2,500 buildings.

The steel skeleton buildings failed badly, on very few columns and girders remaining intact, the terra cotta floors being destroyed very often, and all experts who visited the burnt district agree that no building resisted this fire of 27 hours better than the Junker's Hotel and the International Bank Building, built entirely of reinforced concrete, under the direction of Messrs. Parker & Thomas, Architects of Baltimore. The columns, girders, and floors remained perfectly intact, though the contents were entirely consumed. The fire around this building was so intense that even the brick, which elsewhere held out, were entirely destroyed.

Reinforced concrete buildings will now undoubtedly command lower rates of insurance than buildings

of the same class erected on the old style of steel and terra cotta construction.

The superior fire resisting properties of armored concrete as demonstrated in the most terrible conflagaration at Baltimore deserves the careful consideration of Architects, Engineers, and their clients, who are considering the investment of capital in fire proof structures.

PROPERTIES OF THE COMBINATION OF CONCRETE AND STEEL.

Many eminent scientific men have investigated the properties of armored concrete and established the following facts explaining the great success of the combination of concrete and steel:

First, the coefficient of expansion of concrete and steel is for all practical purposes the same, therefore, no interior stresses can be produced by change of temperature, either in the steel or surrounding concrete.

Second, there exists a surprisingly large adhesion between concrete and steel, amounting from 500 to 700 pounds per square inch of surface in contact. Much doubt has been expressed regarding this adhesion; it is however confirmed by hundreds of experiments here and abroad. Slight rust on the surface of the imbedded bar increases this adhesion by about 10 per cent. Corrugating or twisting of bars also increases it to 10 per cent.

Third, the modulus of elasticity of steel is ten to twenty times, and if the concrete is highly stressed it is about 100 times as great as the modulus of elasticity of concrete. It will be asked how it is possible to figure reinforced concrete structures if such differences

exist. We must admit that the modulus of elasticity varies with the amount of water and cement, the tamping, etc., but all concretes show the fundamental fact that the modulus of elasticity decreases the higher the stress, and is nearly zero at 300 pounds per square foot—that is at the ultimate resistence of non-reinforced concrete. That is to say, in a concrete bar reinforced by steel and subjected to tension stresses exist in the concrete and the steel which are in the relation of 1 to 10, to 1 to 20, at moderate stresses, and when the bar is highly stressed, in the relation 1 to 100, whatever the modulus of elasticity be at the lower stresses.

This means that reinforced concrete stretches considerably at 300 pounds stress by the least increase of tension, and this elongation can reach the elongation of steel at the elastic limit and amounts to about 1 in 1,000. It will now be understood why reinforced concrete girders and slabs deflect considerably before breaking, while we know that non-reinforced concrete breaks without practically any deflection.

This will also explain why reinforced concrete can be used for water tanks, sewers and roofs, which must undergo great changes of lengths through the constant changes of temperature, the steel giving the concrete an exceedingly great elasticity whereby it can undergo these changes without danger of cracking.

Fourth, the steel is completely protected by the con crete from rust and the disintegrating effect of air and water, sea water, or even sulphuric or chlorine gases. We know that iron nails were preserved by the mortar of Roman walls for 2,000 years, and we have not even the least reason to doubt that the far superior

Portland cement will show the same preservative qualities. In order to remove any doubt on the question of the preservation of steel in concrete, engineers induced the city authorities of Grenoble, France, to take up a water main of armored concrete, which had been in constant service for a period of 15 years under a head of 75 feet of water. The sections of the pipe were 6 feet 3 inches long, and the iron skeleton was formed by 30 longitudinal rods, 1-4 inch in diameter, one interior spiral of 5-32 inch wire and one exterior spiral of 1-4 inch wire.

On the 2d of February, 1901, 16 feet of this conduit were taken up. The tubes were found in a perfect state of preservation; the steel did not show the slightest trace of oxidation; the adhesion of the steel to the concrete, despite the slight thickness of the pipes, was such that it could be separated only by heavy blows from a sledge hammer.

SAFETY OF ARMORED CONCRETE CONSTRUCTION.

Vested interests in the old method of buildings which feel their existence threatened by the great inroads this modern building process makes into fields, formerly exclusively their own, are issuing at a great expense trade literature, full of exaggerated accounts of failures of armored concrete floors, declaring reinforced concrete a dangerous novelty, full of uncertainties, etc. Governments have investigated these questions and have decided in favor of reinforced concrete construction.

We see the United States Government adopting reinforced concrete for many important buildings of the United States Naval Academy in Annapolis, for coast and harbor defence, and particularly for gun emplace-

ments, for cisterns and stand-pipes in the different forts on the Atlantic coast, for fire-proofing the Congressional Library, and the new United States printing office, etc.

The few failures which are recorded in this country can always be traced to utter carelessness and utter incompetency on the part of the contractor or his employees. Reinforced concrete is a science like steel construction and nobody can expect that a contractor without any engineering education, and whose only knowledge of concrete is derived from putting in concrete footings or sidewalks, is able to design structures in reinforced concrete.

We find many failures in steel and brick construction due to the same cause. We wish to recall the failures of two coliseums and the works of the Western Electric Company in Chicago, etc.

There are to-day at least 500 million square feet of reinforced concrete floors in use and it is very doubtful whether 1-2 or 1-3 of this area is covered by tile floors.

It can not, therefore, be said that reinforced concrete is a novelty or an experiment. The tests made in this country and in Europe have demonstrated reinforced concrete to be, in the hand of the experienced designer, a material, which can be relied upon more than the best brick, steel or stone construction.

CONSTRUCTION OF RETAINING WALLS.

Reinforced concrete retaining walls are, especially for great heights, nearly 50 per cent cheaper and much safer than solid concrete walls. They consist, as shown in Fig. 90 of a base plate which has a width equal to about 5-10 to 8-10 of the height of the wall, a curtain wall, which varies in thickness from 4 inches at the top to generally not more than 8 inches at the bottom, and vertical ribs from 6 feet to 8 feet apart, connecting the curtain wall to the base plate and making the entire wall an indeformable structure. The horizontal earth pressure increased by the horizontal pressure from loads on the ground, has the tendency to slide the wall on its base, and at the same time, to overturn it, which forces are resisted by the weight of the earth on the base plate. It is clear that the curtain wall is under bending stresses between the ribs from the horizontal pressure and should be designed similar to a floor slab; we have noted the great carrying capacity of reinforced concrete slabs, and, therefore, it is perfectly safe and legitimate to make these curtain walls not thicker than indicated above, however strange it may appear on first consideration. The ribs with the curtain walls form a "T" section, which takes up the bending moments from the earth pressure in regard to the wall as a whole. The base plate is to be designed strong enough to sustain the weight of the earth and superimposed loads, and the reaction of the ground.

We see that every detail of reinforced concrete retaining walls is capable of being figured with certainty in regard to the stresses which are acting upon them.

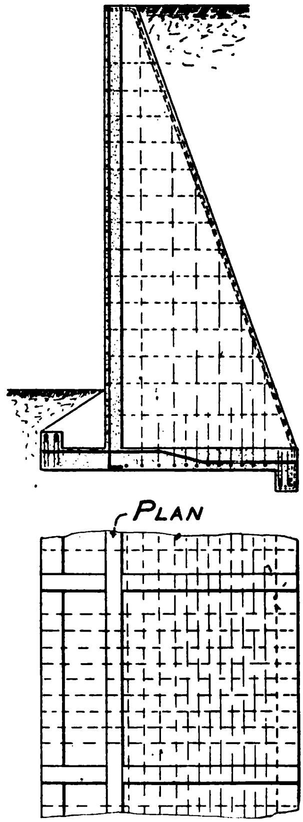


Fig. 90.—Reinforced Concrete Retaining Wall.

We are able to provide a base which can be given to masonary walls only at a ruinous expense; besides, there is no doubt that we know more of the nature of stresses in reinforced concrete than of the distribu-

tion of stresses is a masonary wall, which is affected by lateral forces.

The factor of safety against overturning reinforced concrete walls is thus much greater than that of re-

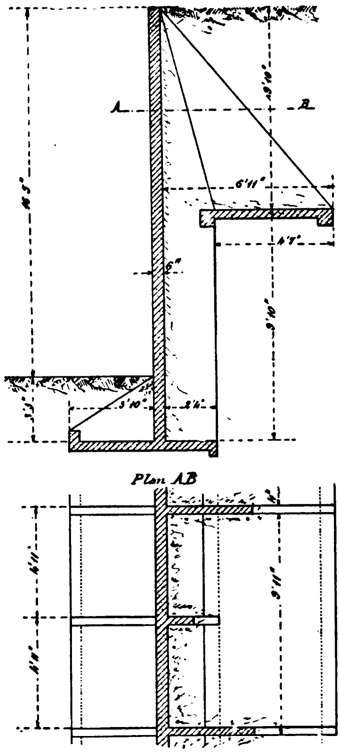


Fig. 91.—Reinforced Concrete Retaining Wall with a platform at Mid-height.

taining walls of any other construction, and from an engineering point of view and from an economical point of view, there is not the least reason why these walls should not be adopted by railroads even for the greatest heights.

Fig. 91 shows a concrete retaining wall of a height of 16 feet with a platform at half the height, which arrangement may save in certain cases a good deal of excavation.

CONSTRUCTION OF REINFORCED CONCRETE DAMS.

These dams are designed on similar lines to retaining walls. We have again a base plate, curtain walls and ribs, making the whole an indeformable structure.

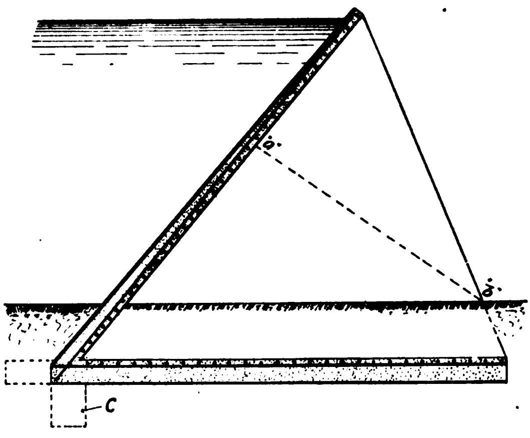


Fig. 92.—Reinforced Concrete Dam.

Figure 92 shows the design of a dam for a head of water of about 15 feet. The curtain walls are inclined at an angle of about 45 degrees to a vertical line to obtain as uniform a pressure on the ground as possible. By this arrangement the pressure on the ground is the sum of the weight of the dam and the vertical component of the water pressure, which is perpendicular

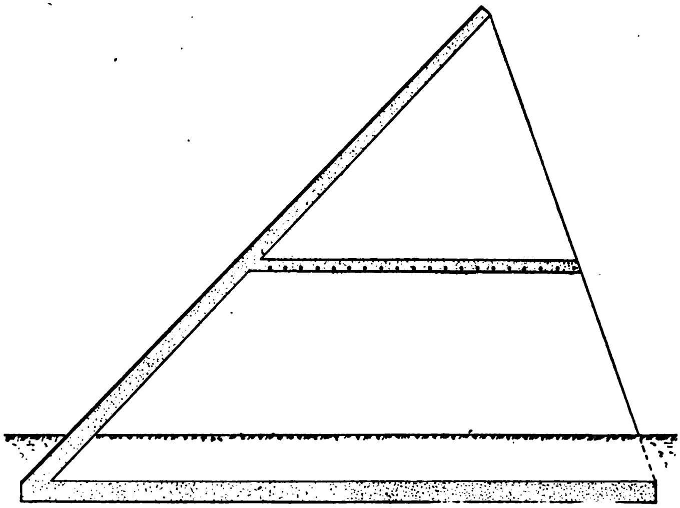


Fig. 93.—Reinforced Concrete Dam with bracing Platform at Mid-height.

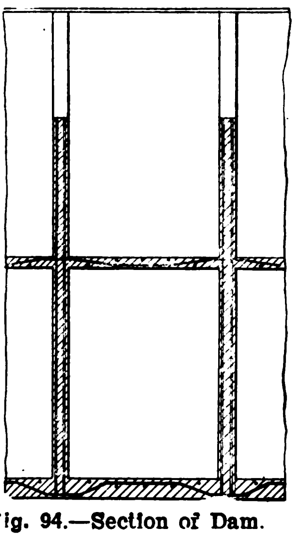


Fig. 94.—Section of Dam.

to the curtain wall, and these two forces have to produce a friction sufficiently large to prevent sliding of the dam on its base.

If there be danger of sliding, the weight on the ground can be increased by filling the inside of the dam with earth up to the line "ab," or by providing a shoe

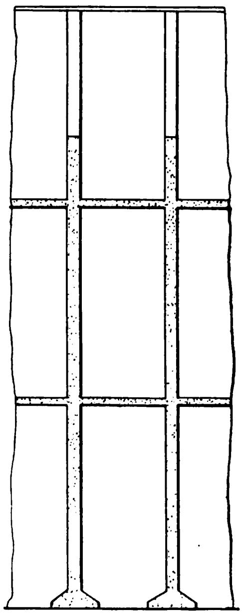


Fig. 95.—Section of Dam 50 feet high with two Platforms built on Rock.

"c," or by extending the base plate towards the water side. The water pressure will then increase the friction on the ground.

Fig. 93 shows the design of a dam for a head of water from 20 to 30 feet. It is good practice as well as economical in this case to introduce at one half the

height a platform connecting ribs and curtain walls which platform reduces the free, unsupported lengths of the ribs and permits a reduction in the thickness of the ribs.

Fig. 94 shows the cross section of this dam.

Fig. 95 shows a cross section of a dam about 50 feet in height, having two platforms to stiffen the ribs and curtain walls. It is here assumed that the dam rests on rock and that the base plate is replaced by footings under the ribs to distribute the weight on the rock. The curtain walls are required to withstand a much greater pressure in dams than in retaining walls. In a 30 foot dam this presure at the base is 1,900 lbs, per square foot. It will very rarely be necessary to make the curtain walls more than 12 inches thick at the base, even under the highest pressure, be-

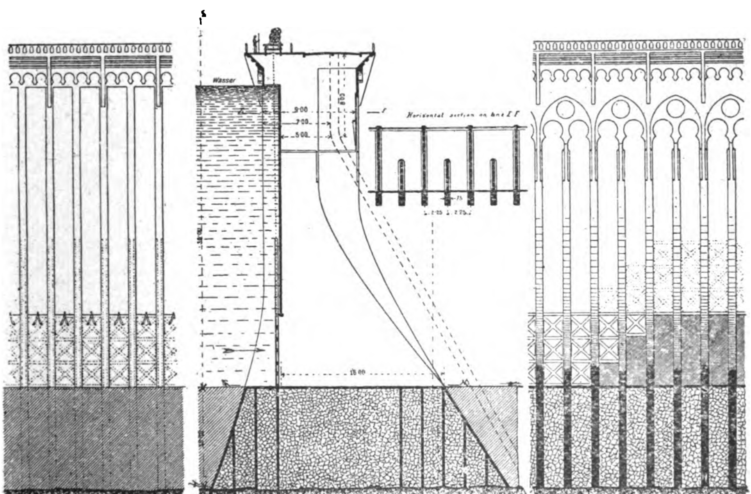


Fig. 96.—Design for the Nile Dam at Assouan, of Reinforced Concrete, 100 feet high.

cause the ribs are only 6 to 8 feet apart. The thickness of the curtain walls can be reduced to 4 inches at the top. Rich concrete should be used for the curtain walls and a 1 inch to 2 inch cement finish is to be applied to the exterior of the wall to insure a water-proof curtain. Fig. 96 shows the design of the Nile dam at Assouan for a head of water of 100 feet. This design was accepted as perfectly reliable from an engineering point of view, but the difficulty of getting enough men, familiar with this class of work, in such an out-of-the-way place, was the single reason that a stone dam of much greater cost was substituted for it.

TANKS, STANDPIPES, CISTERNS, RESERVOIRS.

Tanks and Standpipes are receptacles for liquid above ground.

Cisterns and reservoirs are partly or entirely in the ground. Reservoirs are large cisterns. The cylindrical form is best adapted for these structures, producing in the walls direct tensile stresses, which are taken care of by steel rods, while the concrete is assumed to transmit the stresses to them. We have to guard carefully against expansion cracks by imbedding steel rods also in vertical direction in the walls, and in at least two directions in the bottoms. Where cisterns are situated near rivers, there is sometimes danger, that by an abnormal rise of water the cistern when only partly full may be lifted out of the ground or the bottom fractured. In such cases we have to extend the bottom beyond the walls to get the benefit of the weight of the surrounding ground; and we have also to strengthen the bottom by girders, capable of withstanding the upward pressure. In tanks and cisterns the walls rarely need to be made more than 6 inches thick, even for the largest dimensions, and often 3 inches is quite sufficient. Rich concrete has to be used to insure a waterproof job, which also requires a cement finish 1-2 in. to 3-4 in. thick. This cement finish should be applied as soon as possible after concreting sides and bottom. These surfaces should be carefully cleaned, and a wash of cement applied, before spread-

ing the cement finish in thickness of not more than 1-4 in. at a time. One hour or so should elapse before applying the second coat, giving time to the first coat to get "fat," as the workmen call it.

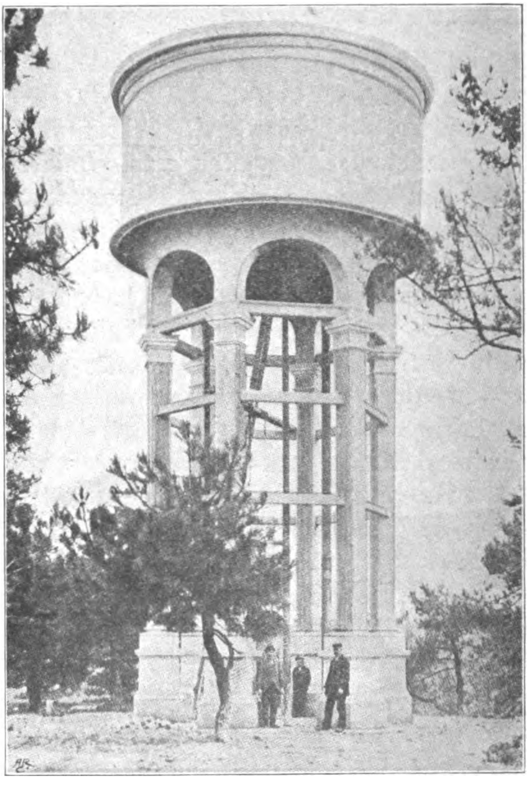


Fig. 97.—15,000 Gallon Tank, at Bournemouth, England. Total height, 45 feet. Inside diameter, 21 feet. Height of tank proper, 10 feet.

Smaller tanks and cisterns up to 30 feet in diameter are covered by domes; the larger sizes by ordinary

column girder and slab construction, as described for floors and roofs. Groined arch coverings as often used in this country are a simple waste of money and

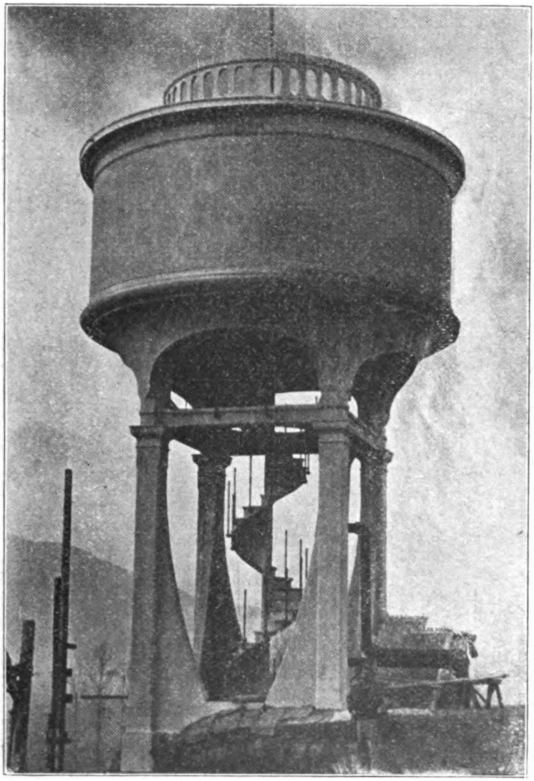


Fig. 98.—20,000 Gallon Tower, Scafati, Italy.

cost at least 50 per cent more. It is of course, possible to make tanks and cisterns, of any other shape, as rectangular, or octognal, etc. In this case the sides of the tanks are subjected to bending, and require much more steel than in round tanks. Cistern walls should

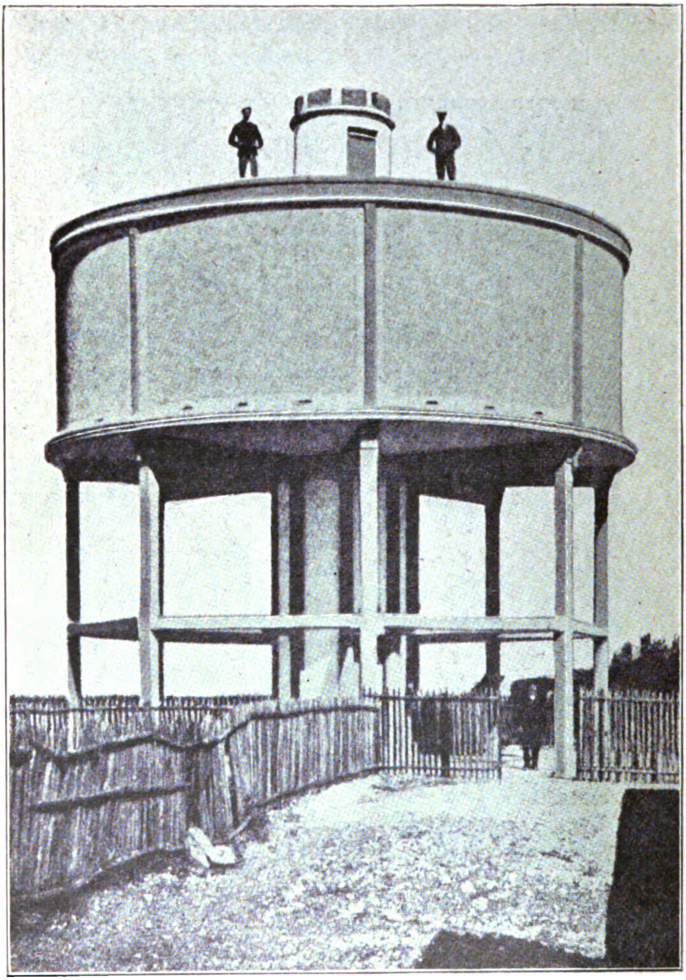


Fig. 99.—65,000 Gallon Water Tank with Hollow Walls. Roof covered with a layer of earth one foot thick. Concrete housing for pipes and pump.

be reinforced on both sides, because when the cistern is empty the walls or sides are acted upon by the outside horizontal earth pressure, subjecting the inside

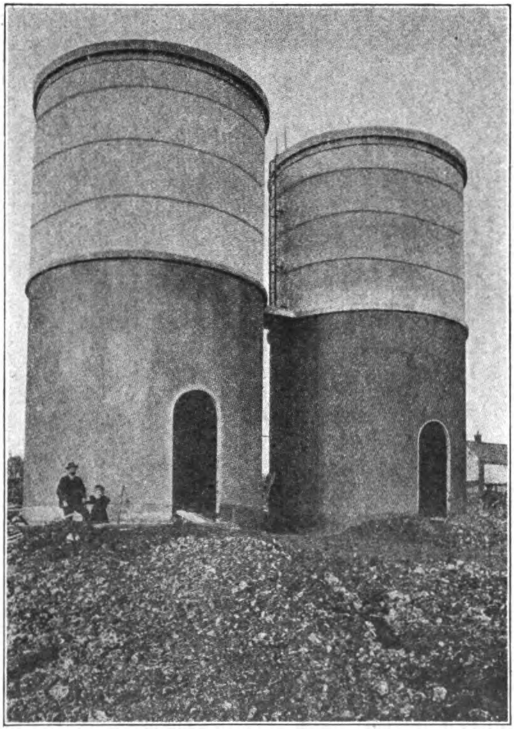


Fig. 100.—80,000 Gallon Water Tanks used by the Government Railroads in France.

of the walls to tension, and when the cistern is filled with water the water pressure will often exceed the earth pressure subjecting the outside of the walls to tension.

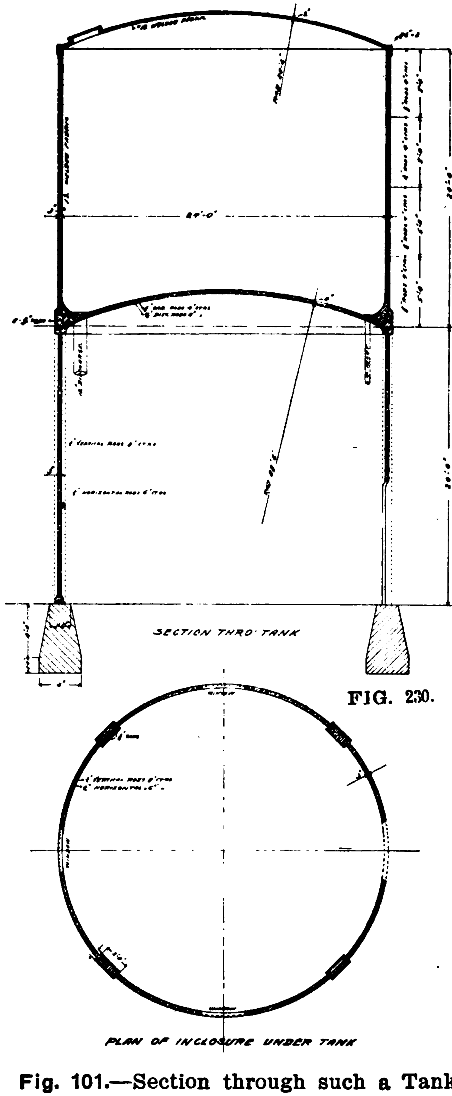


Fig. 101.—Section through such a Tank.

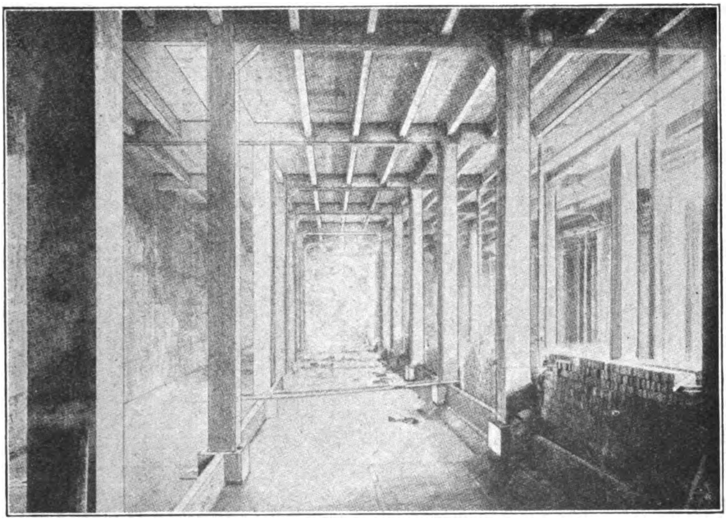


Fig. 102.—3,000,000 Gallon Reservoir for the Water Supply of the City of Lausanne, Switzerland.

The illustrations show some very artistic designs of tanks. They add beauty to buildings or localities when so erected. They are besides much more durable than steel or wooden tanks. They do not incur cost for maintenance and will last for an indefinite time. There are reinforced concrete tanks used by railroads in France, which are over thirty-five years old.

Concrete tanks can be used for storing wine, mineral oils, tar, ammoniac, lyes, salt-water, etc.

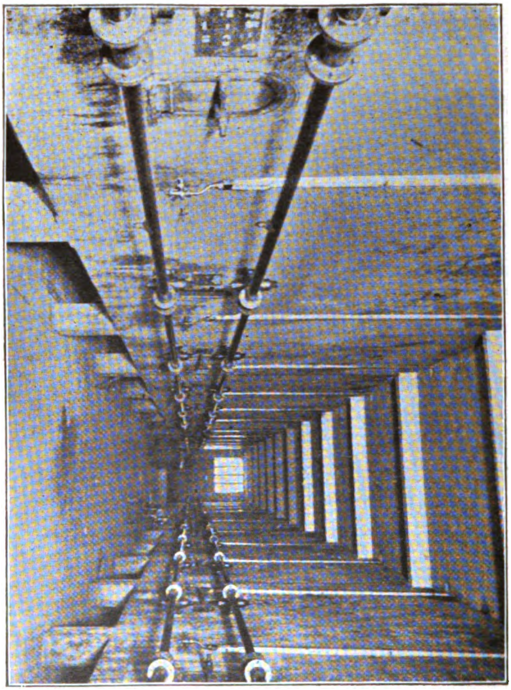


Fig. 103.—24 Wine Vats. Total Capacity, 300,000 gallons.

GRAIN ELEVATORS, COAL AND ORE BINS, LIME AND SALT BINS.

These structures are designed and constructed on lines similar to tanks. The circular form is here also the most economical arrangement; it is, however, often desirable to build elevators and bins in clusters, and in this case, square, rectangular, or hexagonal bins are preferable to round bins. Round bins built in clusters leave a nearly triangular space between them, which is practically lost; where these spaces are filled with grain great bending moments in the adjoining cylinders are produced, which sometimes caused failure of the structure. The horizontal pressure from grain or coal is considerably less than water pressure, and experience proves, if a certain height of bin is exceeded, this pressure is nearly constant on the sides of the bin below this certain height. The sides of rectangular bins if arranged in clusters, must be reinforced on both faces, because one bin may be filled and the adjoining empty and vica versa. The bottoms of the bins are generally suspended from the sides; they sup-

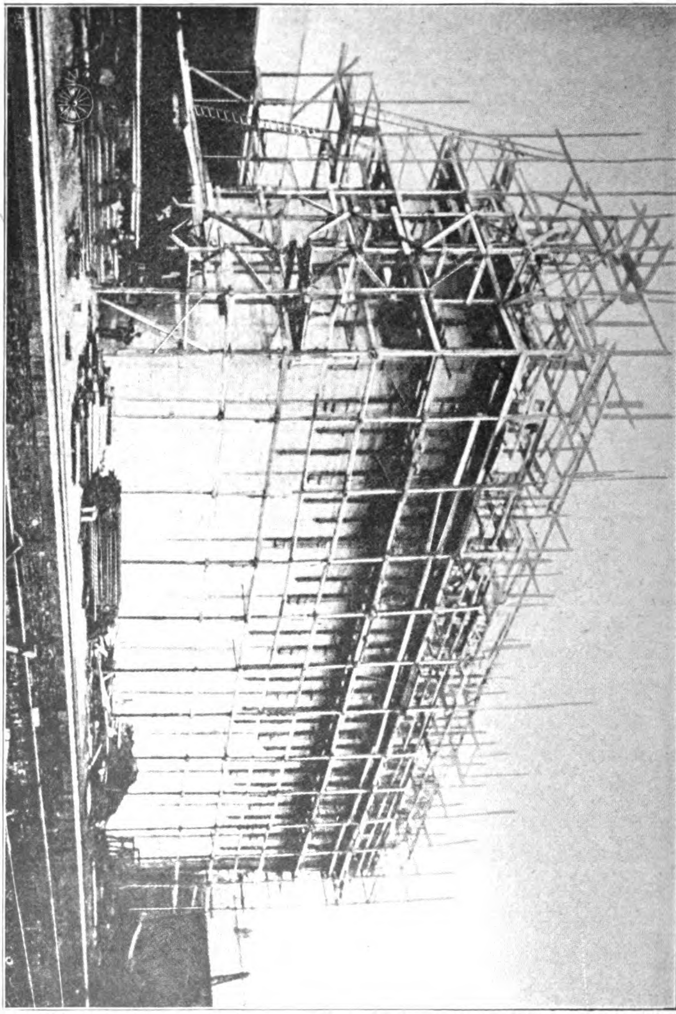


Fig. 104.—Swansea Elevator in Course of Construction.

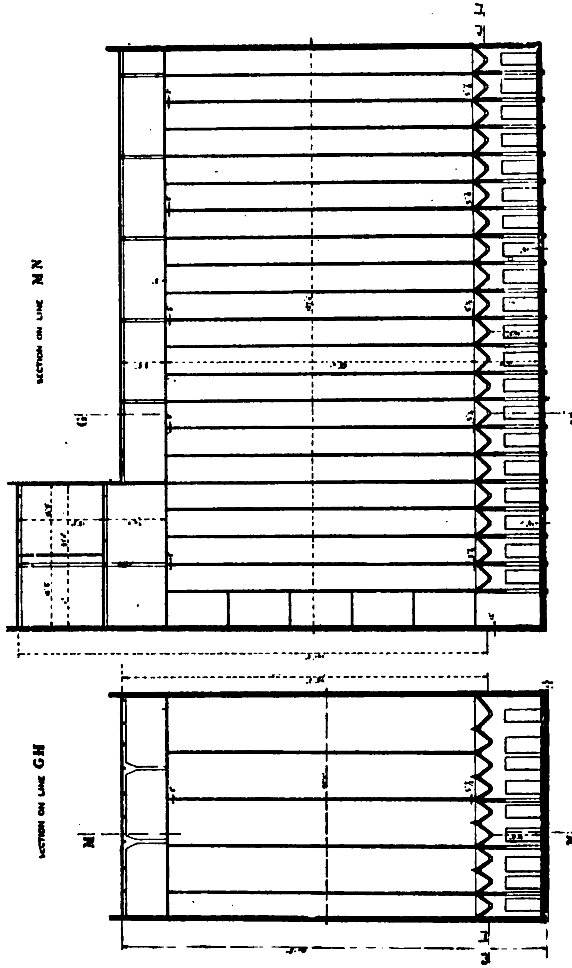


Fig. 105.—Section of Swansea Elevator.

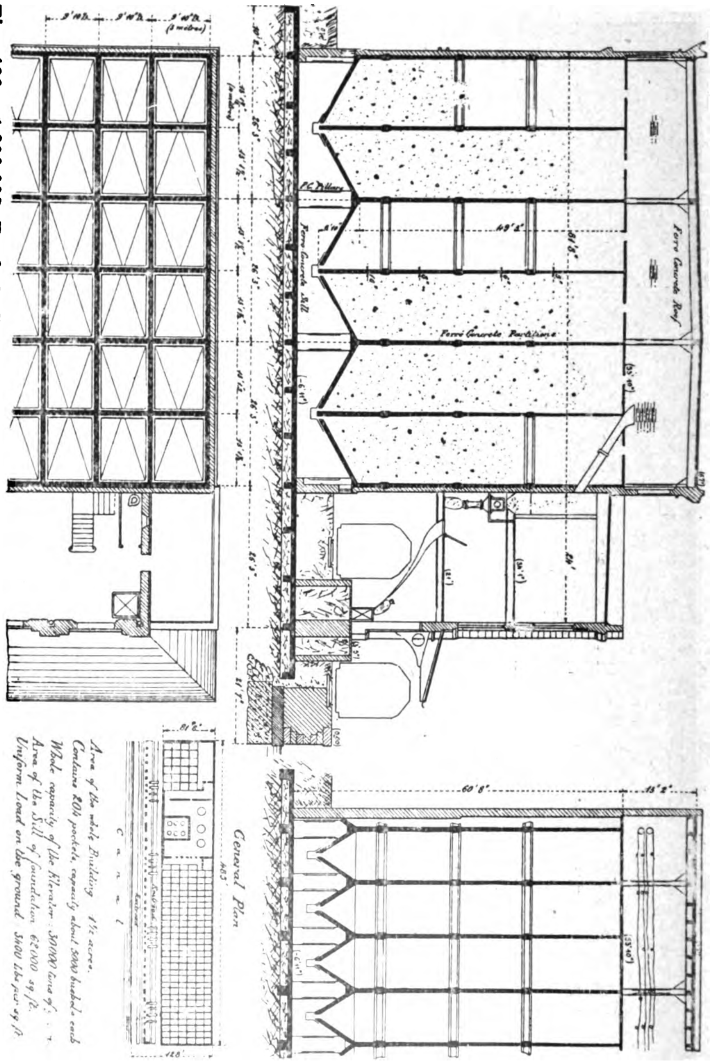


Fig. 106.—1,200,000 Bushel Grain Elevator, Genoa, Italy, of reinforced concrete construction throughout. Reinforced concrete raft foundation.

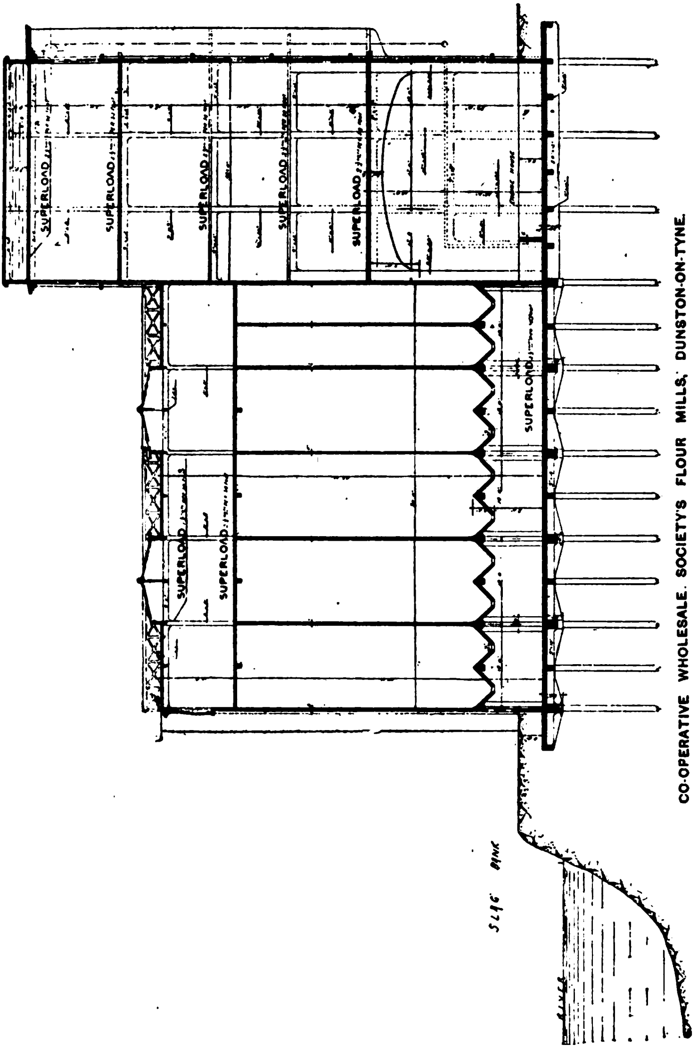


Fig. 107.—CO-OPERATIVE WHOLESALE SOCIETY'S FLOUR MILLS, DUNSTON-ON-TYNE.

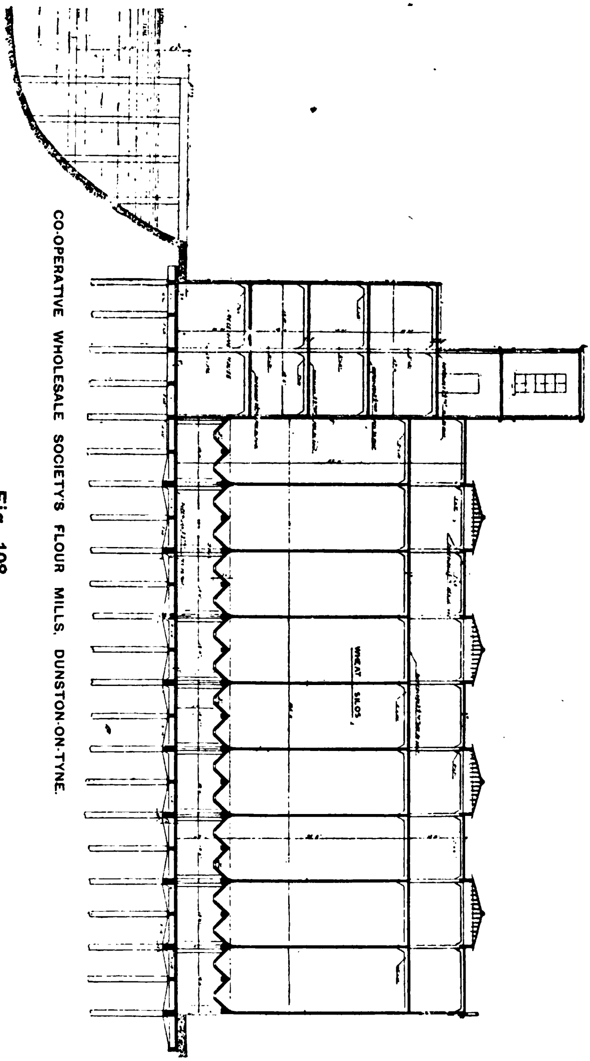


Fig. 108.—CO-OPERATIVE WHOLESALE SOCIETY'S FLOUR MILLS, DUNSTON-ON-TYNE.

port a relatively small part of the weight of the material in a bin, especially, when the height of material is a multiple of the width. A man can easily inter rupt the stream of grain out of a six inch hole at the bottom with his hands, even in the case of high bins, while in a tank the pressure at a six inch opening would be very great.

The thickness of sides and bottoms rarely exceeds six inches, if stiffened by horizontal girders at proper intervals. The bins are generally supported by columns at the intersection of two side walls; and as the bins are very often built near rivers or harbors, where foundations are very bad, a raft over the whole area is generally applied.

Figs. 104 and 105 show a grain elevator at Swansea, England with bins, five feet by ten feet and sixty-six feet high. Fig. 106 shows a one million bushel grain elevator, in Genoa, Italy, with bins 10x14 feet and 57 feet high.

Figs. 107 and 108 show a grain elevator at Dunston-on-Tyne, England, with bins 14x14 feet, and 60 feet high.

Reinforced concrete grain elevators have been used in Europe for more than 20 years. They give perfect satisfaction, do not cause sweating, and are the only type of fire-proof elevators known there.

Fig. 110 shows a coal bin at Lens, Belgium. One of the columns was knocked off by a derailed locomotive, and though the bins were filled, the sides were strong enough to hold up the tremendous weight without cracking.

Fig. 111 shows a coal bin of considerable height. No damage to the sides or bottom is experienced by

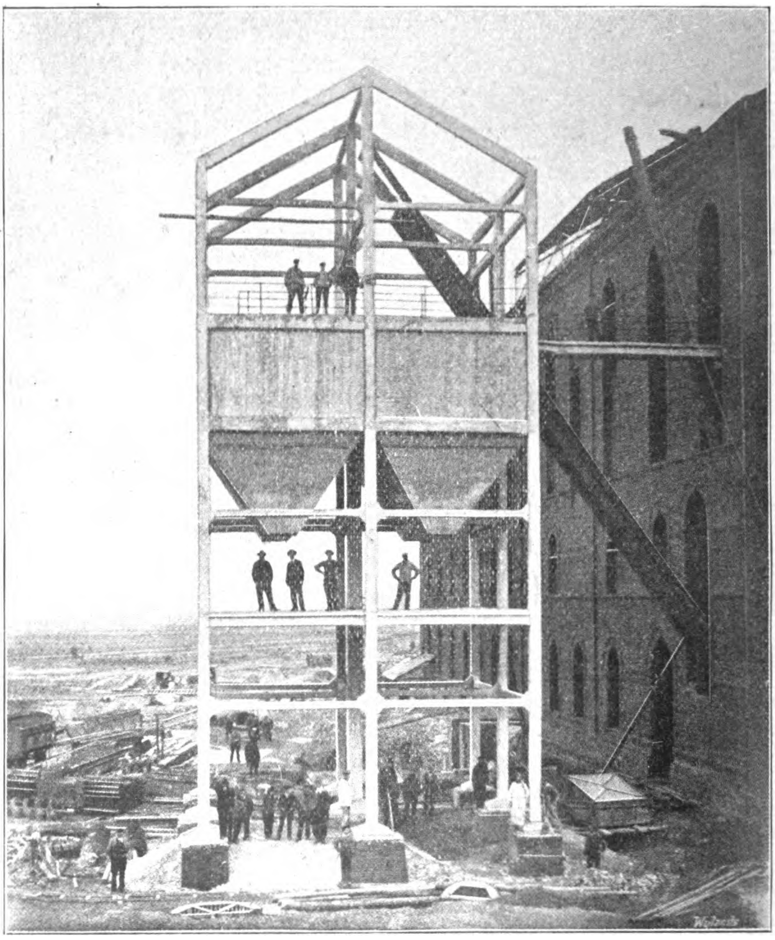


Fig. 109.—Coal Bins, Foot Bridge and Factory of Reinforced Concrete. The bottom of the bin is 28 feet above the ground.

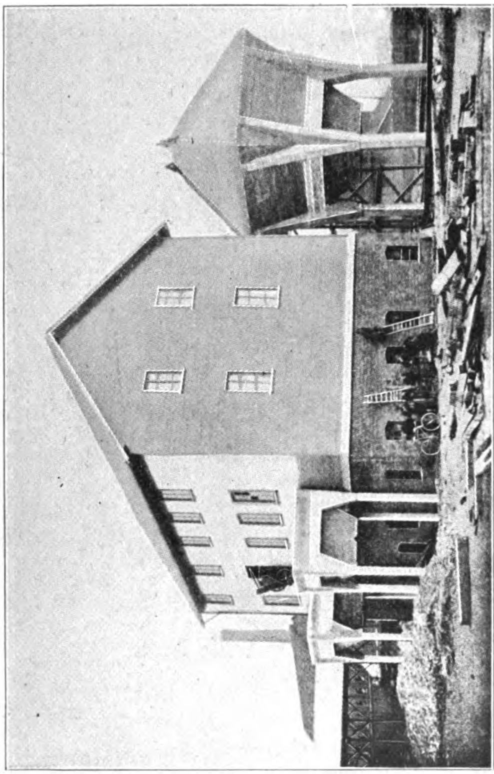


Fig. 111.—Coal Breaker stations, and Coal Bins of Reinforced Concrete.

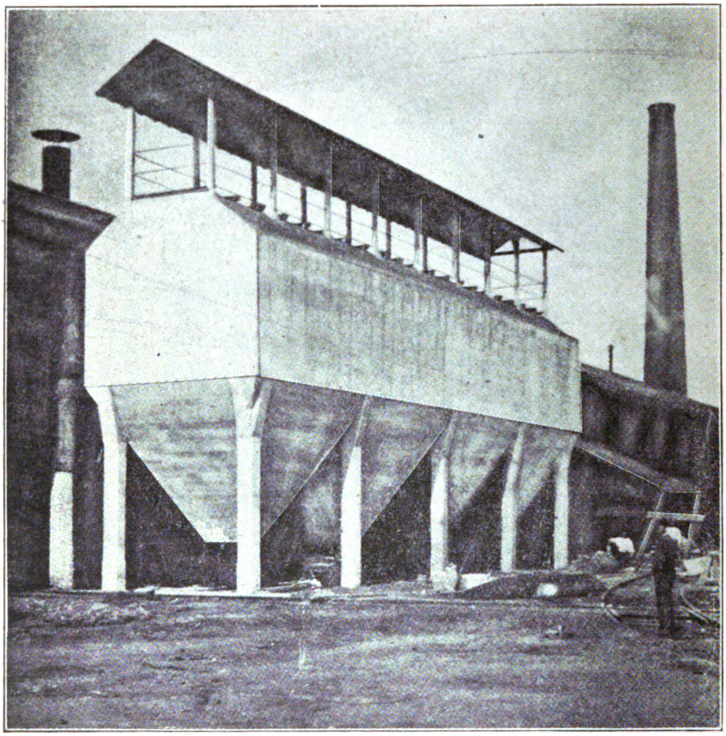


Fig. 110.—Coal Bins.

the dropping of a ton of coal at a time through the opening at the top.

Fig. 112 shows a storage bin, without any inside partitions, built by the Hecla Portland Cement Co., at their works at Edwards Lake, Mich.

This class of reinforced concrete structures is considerably cheaper than steel construction, and undoubtedly will have a great future, also in this country once their great advantages in regard to strength, durability and fireproof qualities are fully understood.

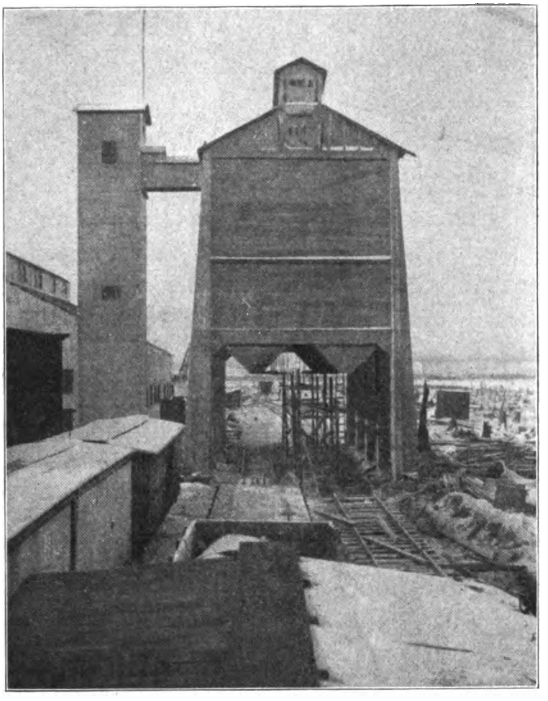


Fig. 112.—Storage Bins, Hecla Portland Cement Co.

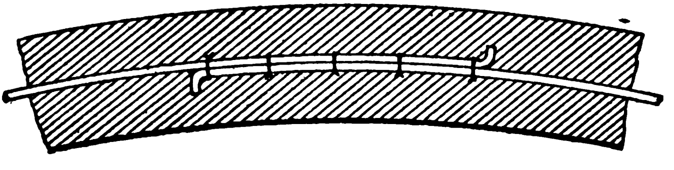


Fig. 113.—Detail of Splicing Reinforcing Rods for Tanks and Water pipes.

REINFORCED CONCRETE WATER PIPES, SEWERS AND CULVERTS.

This branch of reinforced concrete construction belongs to the oldest application of armored concrete.

Water mains are built from 6 inches up to more than 200 inches in diameter, and the thickness of the concrete shell is rarely made less than 1 1-4 inches, nor more than 4 inches. The material used is rich cement mortar in the proportion of not less than 1 part cement to 3 parts sand.

All tensile stresses arising from interior pressure are taken care of by steel rods, which are placed closely together in both circumferential and longitudinal directions, so that the cement mortar acts only as a filling to transmit the stresses to the steel rods and to make the pipes water-tight.

It is good practice to introduce at intervals of from 150 to 200 feet a sliding joint on account of expansion and contraction due to changes of temperature, similar to the expansion joints used in cast iron pipes.

During the first week, after water has been turned on, more or less seepage takes place due to the slight porosity of the cement mortar, which decreases very rapidly by the pores gradually being filled up by the sediment in the water as it passes through the shell, and it is not perceptible after a period of about three months, where the head of water is less than 50 to 70 feet. For higher pressures water-tightness should

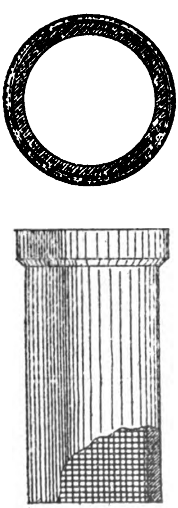


Fig. 114.—Reinforced Concrete Pipe with Hub.

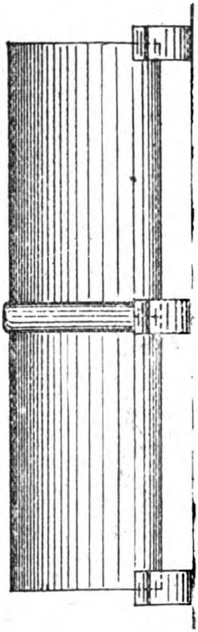


Fig. 115.—Reinforced Concrete Pipe with Sleeve Connection.

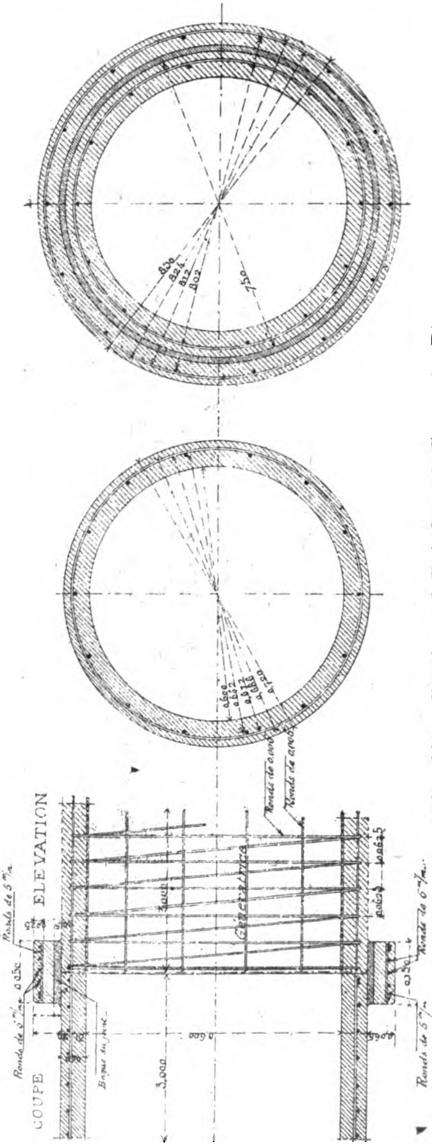


Fig. 116.—Section of Reinforced Concrete Pipe

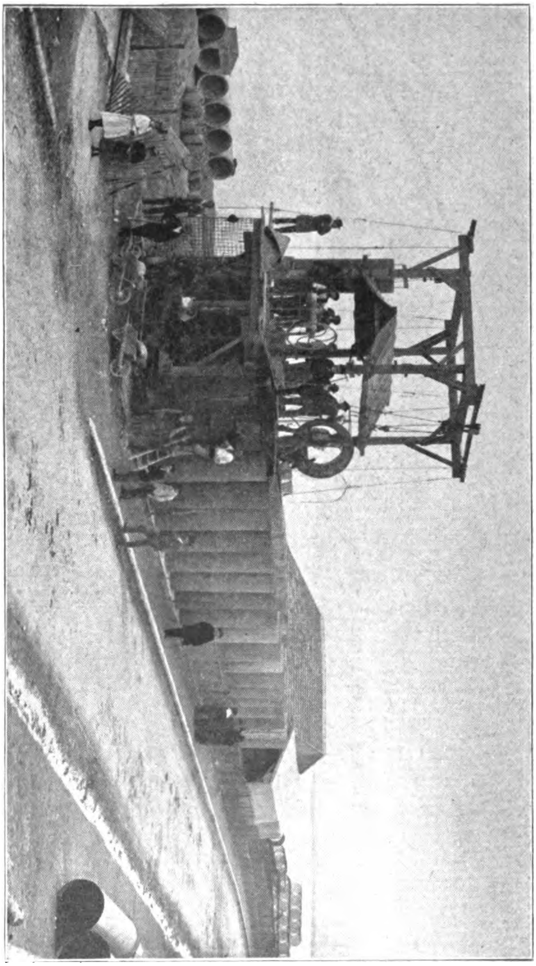


Fig. 117.—Manufacture of Pipes in Movable Works.

be secured by thin sheet steel tubes about 1-16 of an inch thick, which shell for pressures of 250 feet and more is to be increased in thickness to 1-8 or 1-4 of an inch.

The smaller pipes are manufactured in a factory or in movable works, near the place where they are to be used, in lengths from 3 to 15 feet, and have either hub and flat eend connction as shown in Fig. 114, or sleeve connections, as shown in Fig. 115.

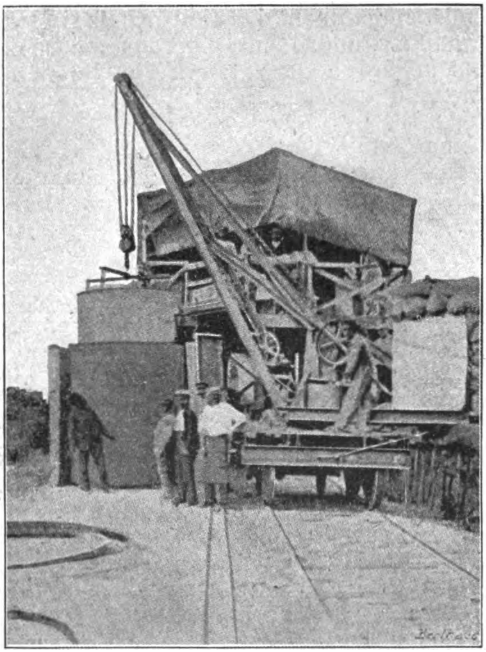


Fig. 118.—Manufacture of Pipes in Movable Works.

The water-tight joint is made by pouring rich cemet mortar into the space between the pipe and the hub or the sleeve.

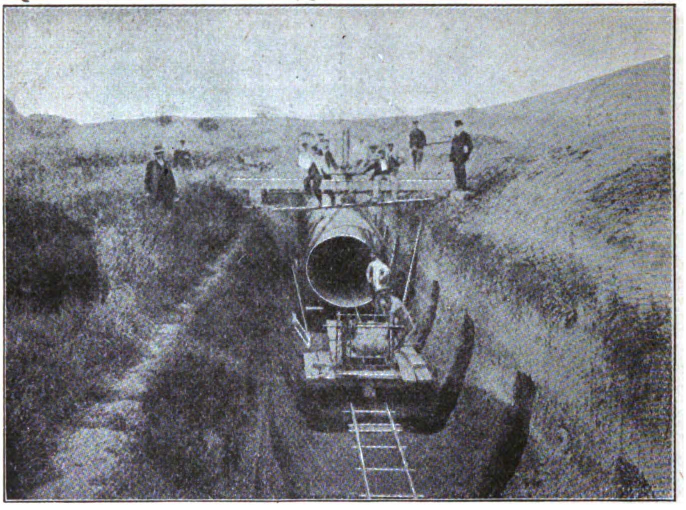


Fig. 121.—Pipe of 5 feet 9 inches diameter. Paris Sewage Disposal System.

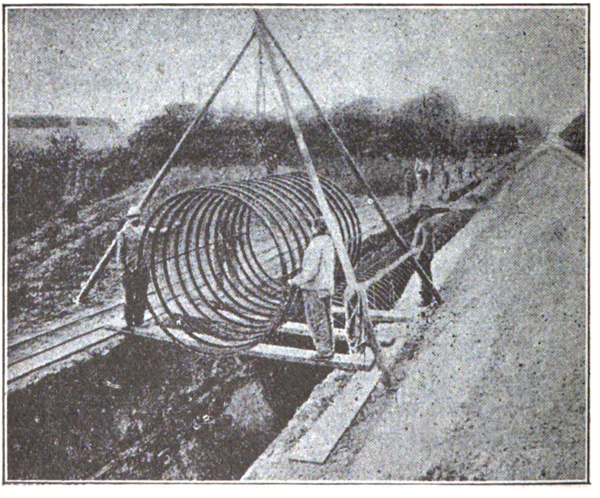


Fig. 122.—Manufacture of Reinforced Skeletons.

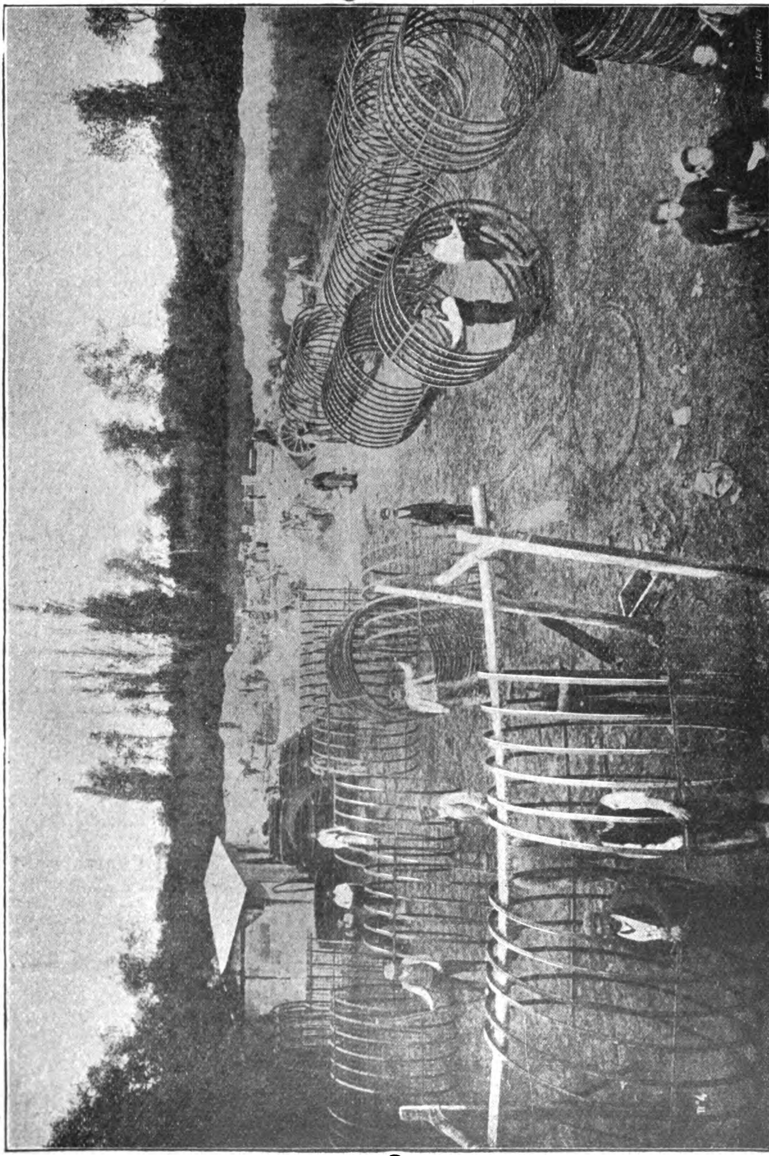


Fig. 123.—Manufacture of Reinforced Skeletons for circular Sewers, Paris.

Larger pipes are built up in the trench by the aid of movable centerings, making the whole pipe line one monolith.

There is very little danger of the sheet steel lining corroding, because the enclosed air is under high pressure and does not attack the steel. In some cases it might be advisable to protect the inside of the lining by an inner reinforced concrete pipe.

Fig. 117 to 123 show the manufacture of reinforced concrete pipes of medium diameters.

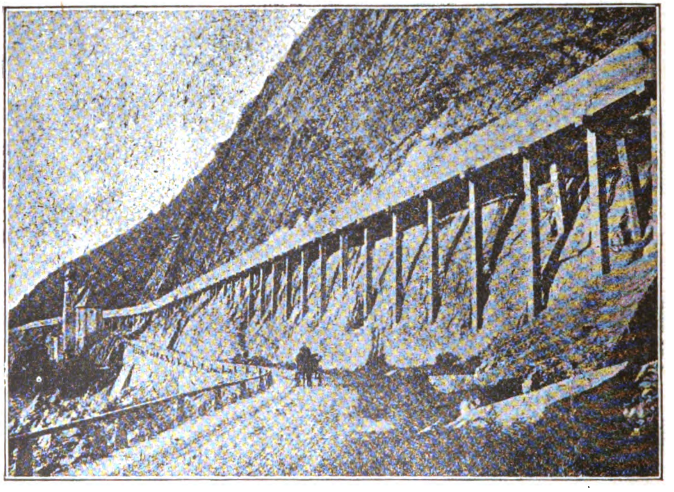
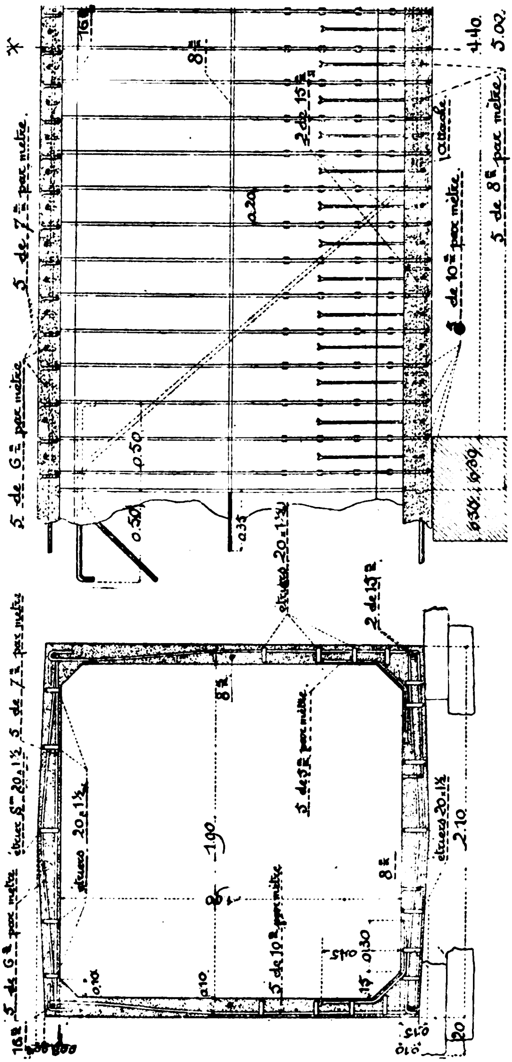


Fig. 124.—Reinforced Concrete Flume on Reinforced Concrete Trestle conveying the Water of the River Rhone to the new Simplon Tunnel.

Fig. 124 to 126 show a flume built of reinforced concrete to supply water from the River Rhone to the 2,000 H. P. turbines at the mouth of the new Simplon tunnel. It has a square section, 6 feet 4 inches inside, the walls being 4 inches thick. It is 9,800 feet long and runs partly in the ground and partly on a rein-



Figs. 125 and 126.—Details of Flume.

forced concrete trestles, in some places 30 feet high, and it also crosses two streets on canal bridges of 35 feet span.

The cost of a wooden flume would have been 85 francs per lineal meter, while the reinforced concrete flume was built for 100 francs per meter. Considering that the water power is to be a permanent feature of the tunnel to supply electrical power required for moving the trains through the tunnel, it is clear that reinforced concrete in this case was the most economical form of construction.

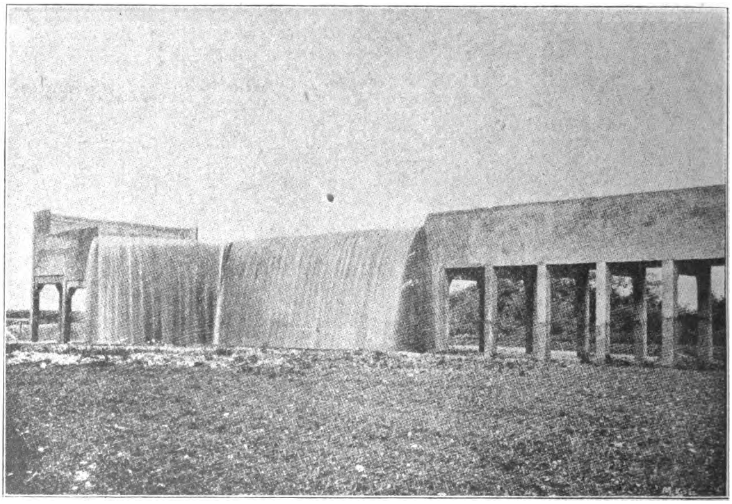


Fig. 127.—Power Canal and Spillway.

REINFORCED CONCRETE SEWERS.

Reinforced concrete sewers are built on lines similar to water mains. The most favorable section in this case is not a round, but a parabolic shape. The steel reinforcement is not required to be as high as in

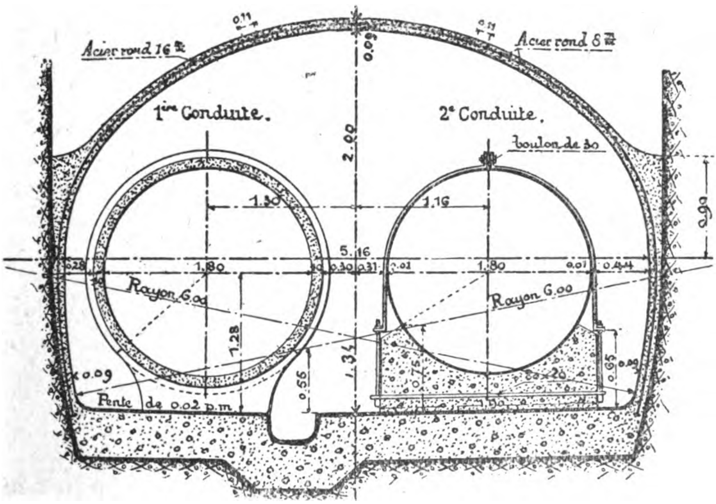


Fig. 128.—Section through Tunnel 17 feet wide, and Reinforced Concrete Sewer for Sewage Disposal System of the City of Paris.

water mains. There is little danger of a sewer being injured by super-imposed loads, as a parabolic arch of a thickness of only 3 to 4 inches has an enormous carrying capacity, as shown, for example, in Fig. 128, representing a 17 feet tunnel covered by 17 feet of earth, which was built of a shell of armored concrete less than 3 inches thick, and was tested by a movable load of 11 tons without any sign of weakness, deflecting under this concentrated load not more than 1-25 of an inch.

Filling of the trench on one side only will be a source of great danger to the concrete shell, if this unsymmetrical load has not been provided for in the original design.

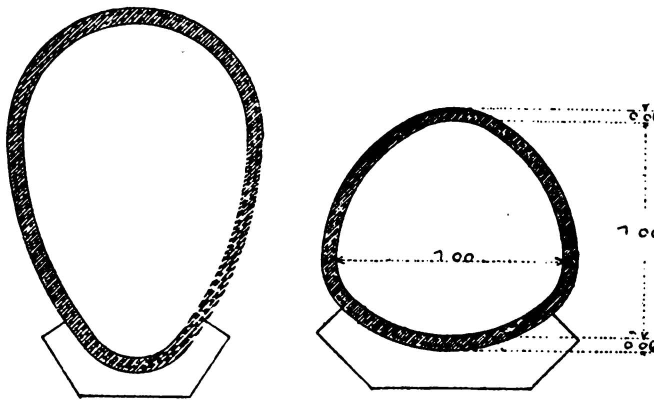


Fig. 129.—Sewer Sections of small Diameters.

Inasmuch as the greatest portion of the weight of the earth is above the crown of the sewer, the designer is liable to fall into the error of not duly providing for the strains to which the sewer is subjected during the filling of the trench. It is apparent that the invert of the sewer must be amply reinforced to withstand the upward pressure of the ground, due to the weight of the sewer and the super-imposed loads.

There are many sewers built in the United States of diameters of 10 to 15 feet, having a thickness at the crown of 1 1-2 to 2 feet. This is often an extravagant waste of money and material.

Where sewers must be built on treacherous soil it may be of advantage to drive piles every 10 feet, and to make the shell of the sewer to act as a girder between the piles, able to carry itself, its contents, and the super-imposed loads.

Nearly all of the cities in Europe have abandoned brick sewer construction, and substituted reinforced concrete.

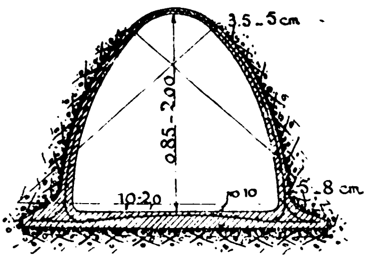


Fig. 130.—German Sewer Sections, of Reinforced Concrete Construction.

Fig.. 130 shows a section of a sewer as it is adopted in most cities in Germany.

The City of Paris in the construction of its sewage disposal system adopted reinforced concrete exclusively and has about 17 miles of conduits up to 10 feet in diameter, in successful operation. See Figs. 121 to 123.

Large factories exist all over Europe, producing pipes and conduits of various shapes, sizes and diameters, notably the Dykerhoff & Widemann factories, which employed in 1900 two thousand five hundred men.

Fig. 131 is a view of one of these factories.

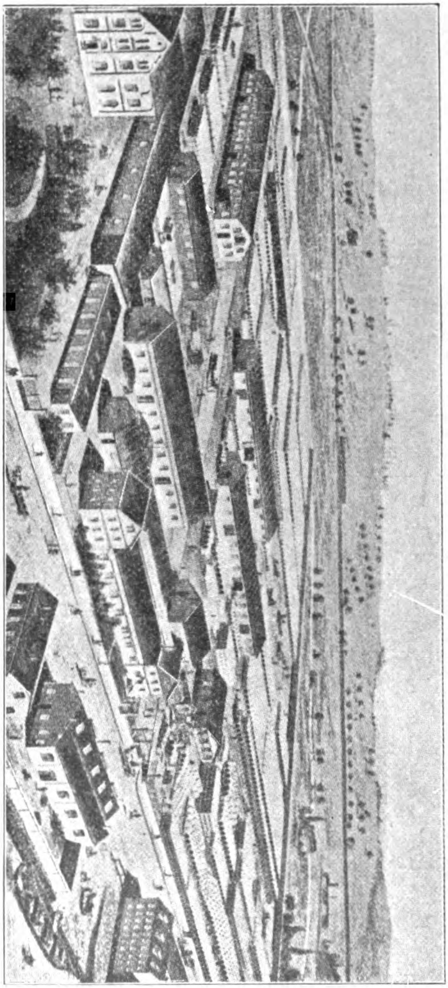


Fig. 131.—Factories of the Dykerhoff & Widemann Co., for the manufacture of reinforced concrete pipes.

REINFORCED CONCRETE CULVERTS.

American railways are improving their right of way by permanent concrete culverts, and while they used up to a very recent date only massive concrete construction, they are now beginning to appreciate the great economical advantages of a well designed reinforced concrete culvert. The most economical form is of a parabolic section and almost any thickness of shell will be capable of supporting the heaviest super-imposed loads provided that due precautions are taken to avoid eccentric stresses during the process of filling the earth around it.

Where the high parabolic section is not exactly suitable, a culvert, consisting of vertical side-walls and of a parabolic or flat covering, may be substituted.

The side-walls must be figured for the lateral earth pressure as well as for the horizontal pressure due to the live train loads on similar lines as described for basement and retaining walls. The flat cover may be a reinforced concrete slab for spans less than ten feet or of girder and slab construction for larger spans.

MISCELLANEOUS APPLICATIONS.

To enumerate or even specialize the almost universal application of reinforced concrete is a task far beyond the scope of this handbook.

Therefore we will describe only a few of the most important uses.

REINFORCED CONCRETE SMOKE STACKS.

Many reinforced concrete smoke stacks have been built in this country and Europe during the past 15 years. These stacks are much stronger than solid or hollow brick chimneys, and can be erected, not only in a much shorter time, but also at very great reduction in cost.

Figs. 132 and 133 show a concrete chimney erected by Mr. C. Leonardt, Los Angeles, California, for the Los Angeles Electric Railway Power Station. It has an inside diameter of 11 feet and is 155 feet high above grade. It consists of solid concrete masonry up to 36 feet above the ground; from there up of an outside and an inside shell of reinforced concrete, which latter can expand independent of the outside wall.

Fig. 134 shows the movable mold used for concreting the shell's.

In Fig. 78 is shown a chimney 130 feet high built of a solid shell of reinforced concrete.

Fig. 135 shows a lime kiln built of a shell of reinforced concrete lined with fire brick, which stood for

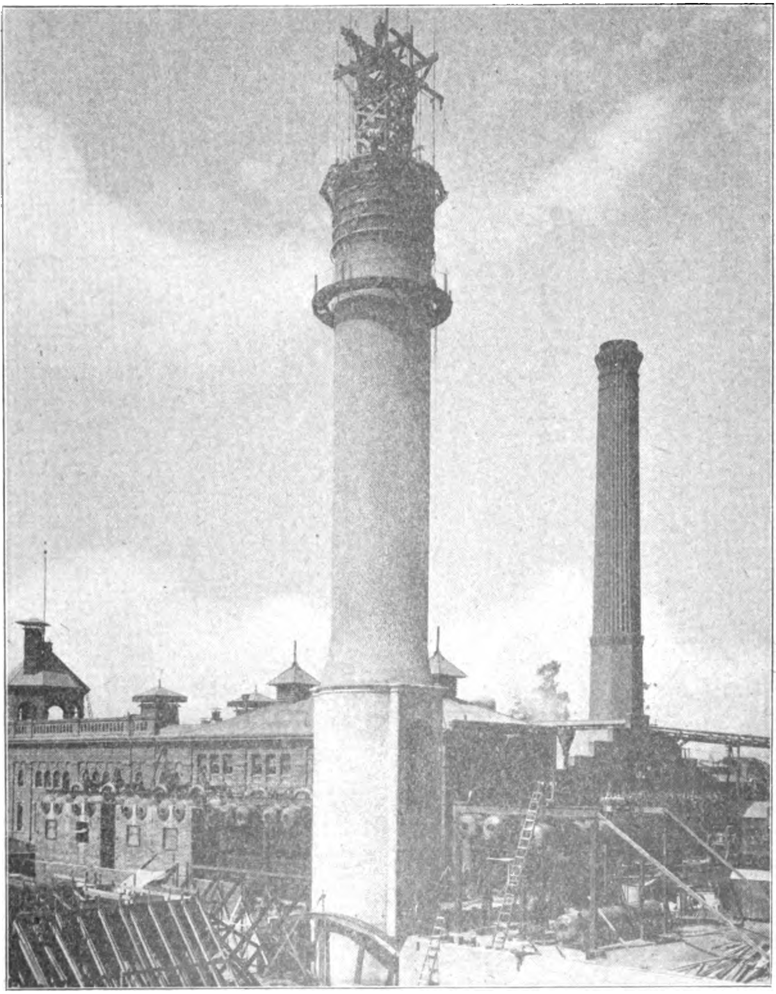


Fig. 132.—Reinforced Concrete Chimney, in course of erection, Los Angeles.

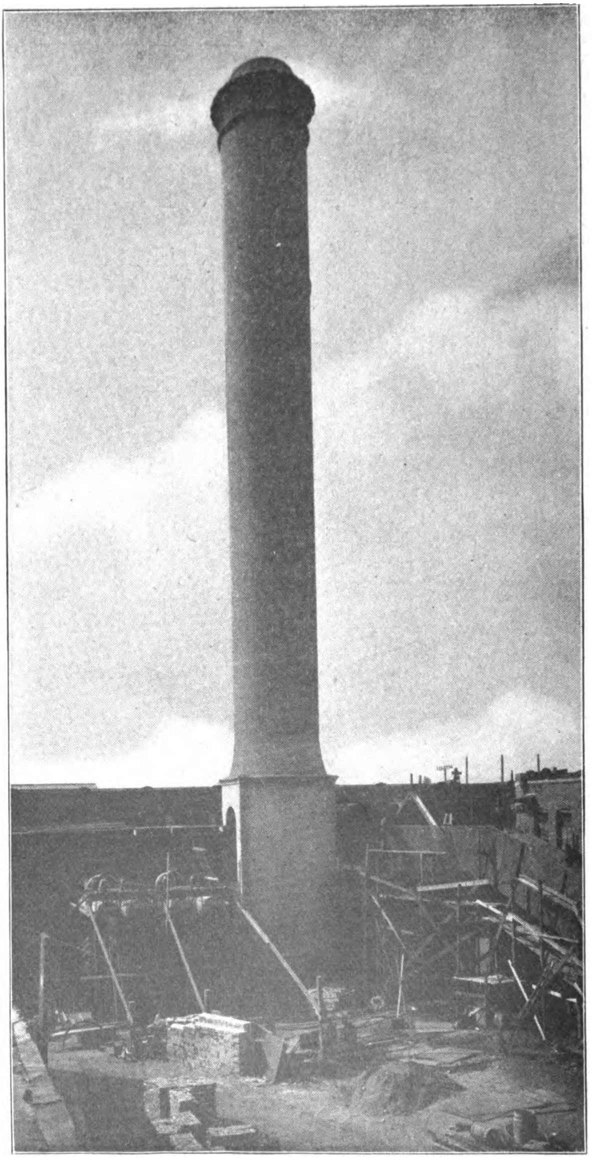


Fig. 133.—Completed Chimney for Los Angeles Power Co.

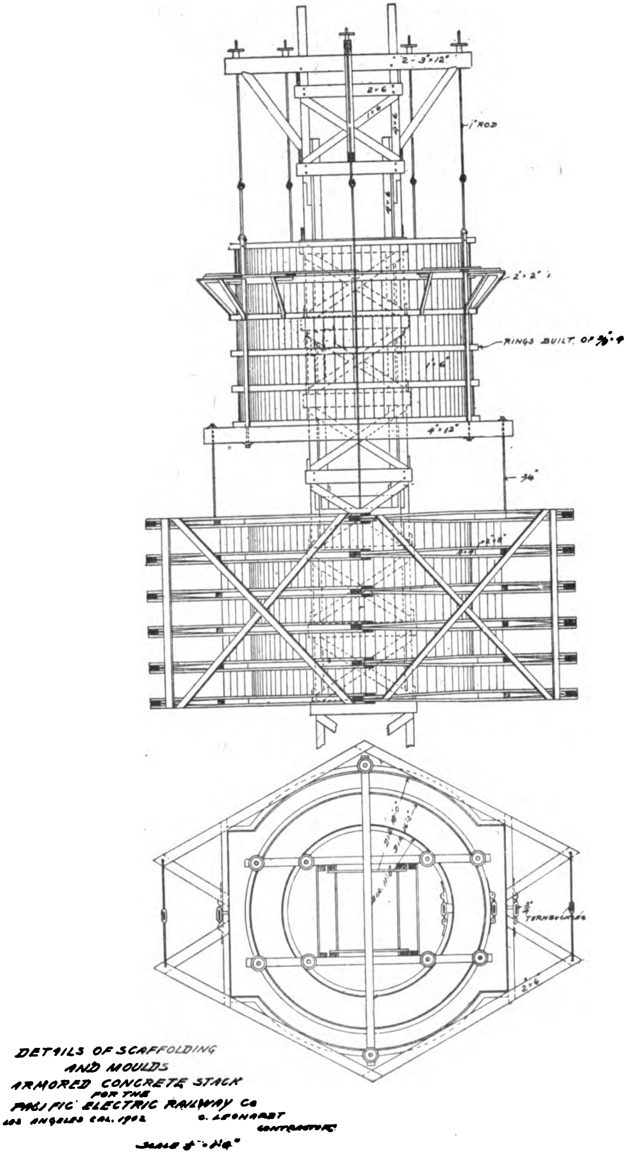


Fig. 134.—Movable Centerings for this Chimney.

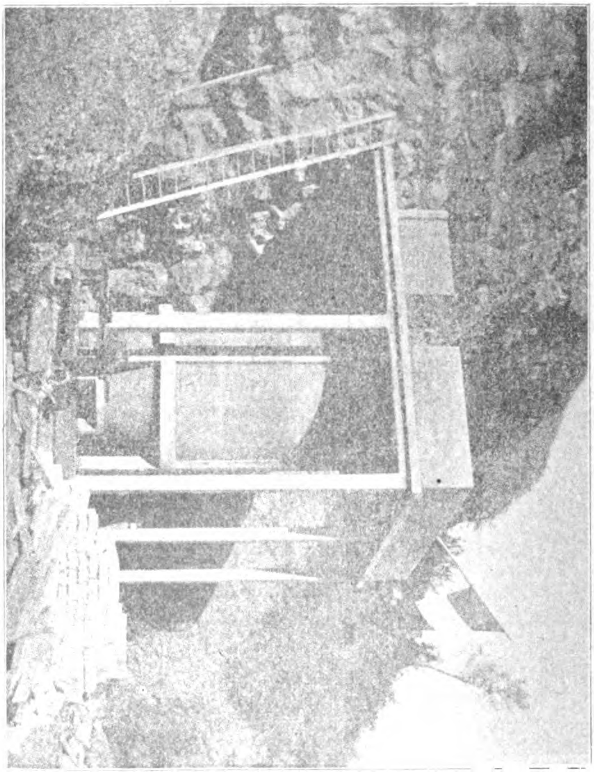


Fig. 135.—Limekiln of Reinforced Concrete, Firebrick lining.

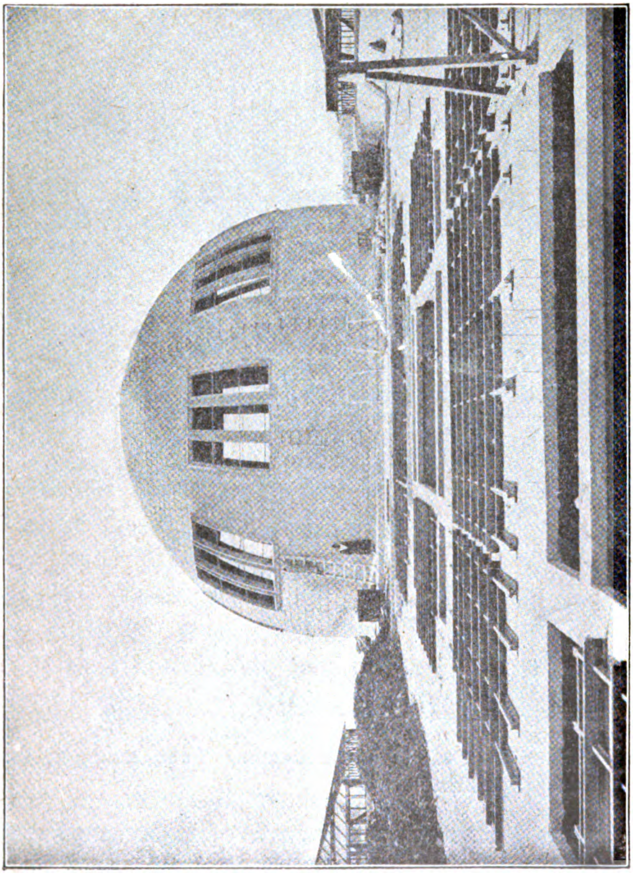


Fig. 136.—Dome of 60 feet diameter. Museum of Egyptian Antiquities, Cairo.

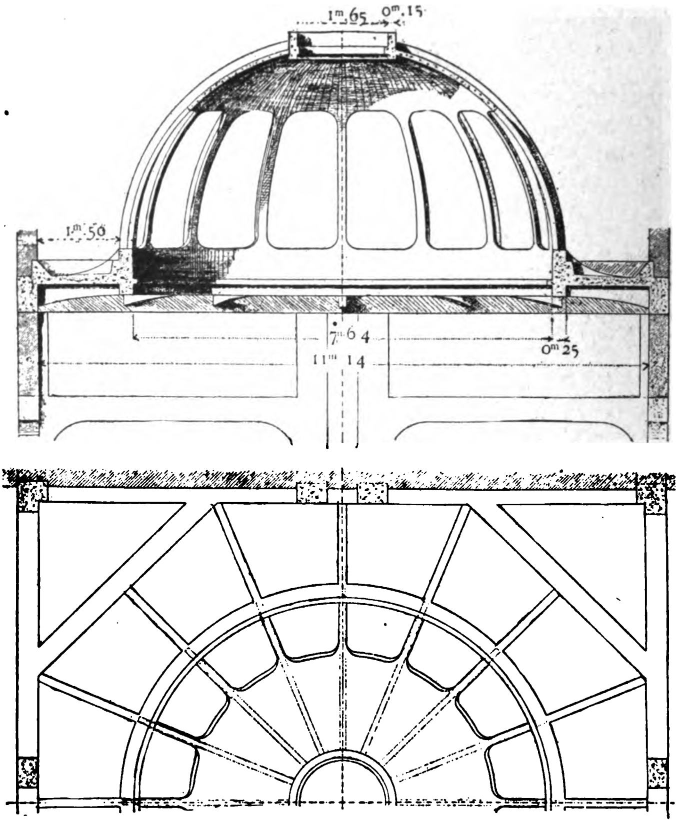


Fig. 136b.—Dome of 40 feet diameter. Bank Brunner, Brussels, Belgium.

years has withstood temperatures of 2,000 to 2,200 degrees Fahrenheit.

Fig. 136 shows reinforced concrete domes of daring design. There is no material which is better adapted for this class of structures than reinforced concrete. Even for the largest diameters a thickness

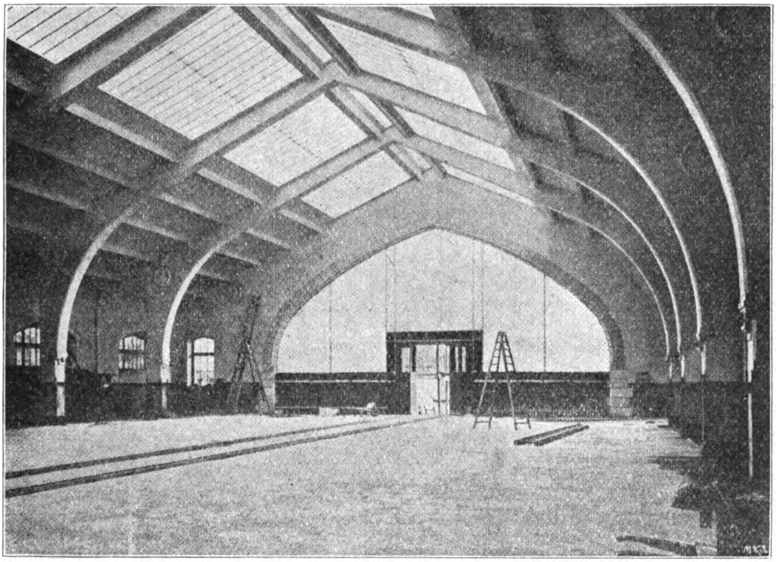


Fig. 137.—Printing Establishment, Rennes, France. Arches of 80 feet span.

of three inches at the crown and five to six inches at the springing is quite sufficient.

Fig. 137 shows a hall for a printing establishment at Rennes, France, consisting of concrete arches of 81 feet span, concrete purlins and a concrete roof with skylights. Reinforced concrete arches can be built at very reasonable expense up to 200 feet in span and over for railroad stations, public halls, factories, etc., and possess many advantages over steel arches. They are fireproof and indestructible, cost much less, can be maintained at very little expense, have a fine architectural appearance and afford better light for the interiors.

Fig. 138 shows a railroad tower built of reinforced concrete. The French railroads build small guard

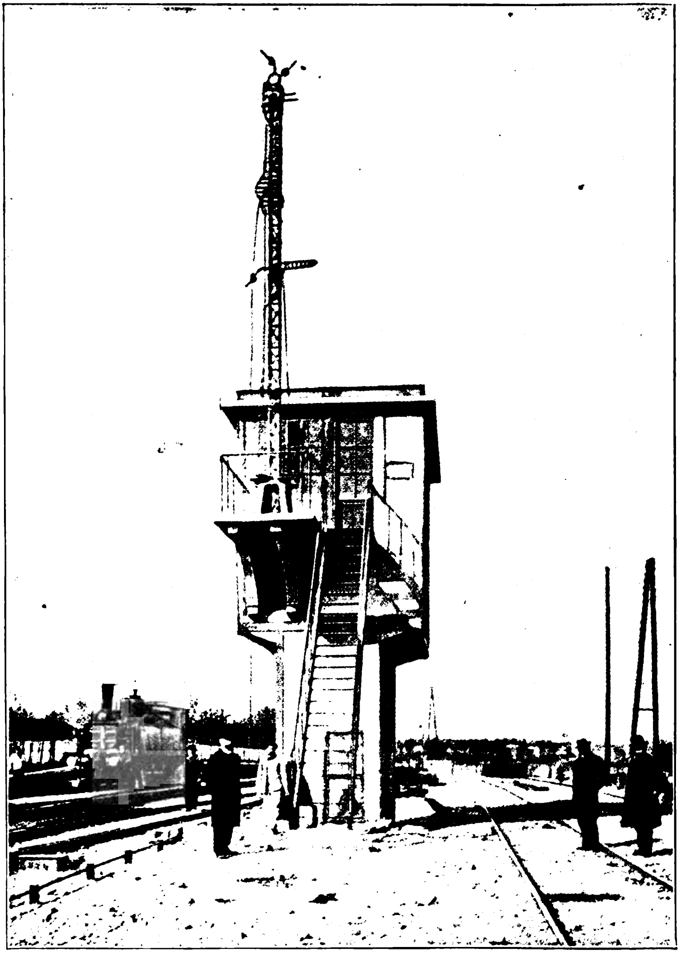


Fig. 138.—Railroad Guard Tower used by French Railroads Foundations are enlarged for greater stability.

houses of reinforced concrete and ship them completely finished on cars to the places where they are to be used.

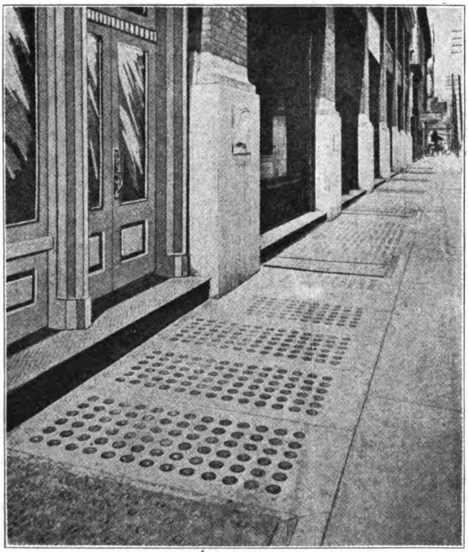


Fig. 139.—Reinforced concrete side-walk lights, Power Building, Cincinnati, built by the Ferro-Concrete Construction Co. Cincinnati.

Figs. 139 and 140 show prismatic sidewalk lights with reinforced concrete framing. The glass inserts are two and three-fourths inches in diameter and three and three-fourths inches on centers, while the concrete frame is one and three-fourths inches thick, strengthened by small steel rods in both directions. Nearly all the subway stations of the New York Rapid Transit Railway have reinforced concrete sidewalk lights.

Leading American railways are now experimenting with reinforced concrete ties, with a view of displacing

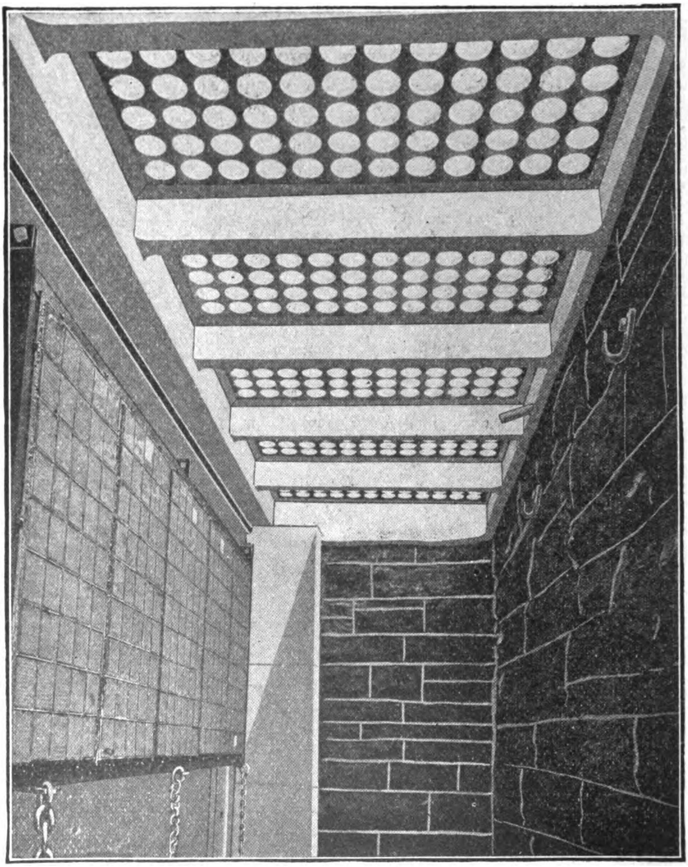


Fig. 140.—View of Reinforced Concrete Side-walk Lights from below.

the ordinary wooden ties which are yearly becoming more expensive.

The Italian government, after experimenting several years with reinforced concrete ties, has adopted a standard concrete tie on all the government railways.

The French railroads in China on their right-of-way of over 300 miles, use reinforced concrete ties exclusively, having an inverted "T" section, with an enlargement of the stem, where the rails cross, which ties cost about two and a half dollars each.

These ties are much more expensive, in the first instance. Their greater life, however, after 10 years' use, will result in decided saving.

Reinforced concrete fence posts are rapidly coming into use in the United States, by railroads along their right-of-way, especially, in prairie countries where fire hazards are great. Statistics show that 60 per cent. of the fence posts of the right of way are destroyed by fire against 40 per cent. by decay.

Reinforced concrete is likewise coming into extensive use for agricultural purposes, as, for example, for small water and feed tanks, silos, for irrigation ditches etc.

REINFORCED CONCRETE BRIDGES.

Reinforced concrete combining the massive effect of brick and stone and the great strength of steel has found a great field of application in bridge building.

The rapid progress accomplished in bridge construction during the last 30 years is due to the use of steel, which, being of relatively small weight, enabled engineers to erect large spans without the use of costly scaffolding. Both iron and steel are liable to deterioration by rust, and as some parts cannot easily be inspected or painted, the life of a steel bridge is very limited, and steel bridges are to-day considered as temporary structures.

Consequently the first class railways in this country are again returning to stone or solid concrete bridges which offer the advantage of great stiffness and durability.

The use of steel reduced the cost of bridges to a considerable extent; engineers continually increased the working stresses to be allowed in the calculation of the bridge members, and the result is light bridges, which are liable to be wrecked in a short time by the continuous traffic of ever increasing loads. Reinforced concrete bridges can be expected to last for ever; just as the old Roman concrete walls outlasted their stone linings, even so can we expect concrete bridges to outlast stone bridges. Repairs and cost of maintenance are reduced to a minimum; they can be built at a reasonable cost, very often for less money than steel

bridges; they are 10 to 20 times more rigid than the latter.

The first application of reinforced concrete in bridge construction was in concrete floors of steel bridges, especially in city bridges where a permanent floor was required.

The usual distance of stringers in steel bridges is 3 to 5 feet, and it is perfectly feasible to cover them by a concrete floor 1 1-2 to 2 inches thick, capable of supporting any concentrated or distributed load, which may come on the bridge. Reinforced concrete now replaces the very expensive floorings, which were formerly made of buckle plates, suspension plates, or various kinds of trough floors with a covering of concrete.

These concrete floors are not only more durable but also much lighter, saving a great amount of dead weight and, therefore, steel in the bridge and costing less than the old floorings.

The next application of reinforced concrete in bridges was due to the demand of railroads for viaducts of very limited depth for street and railroad crossings. For railroad crossings it was possible to span distances up to 20 feet by a reinforced concrete slab. only six inches thick, while for street crossings a thickness of 12 inches for a span of 10 feet has proved very satisfactory.

Fig. 141 shows a cross section of such a flat bridge of 10 feet span, carrying a railroad track of the Jura

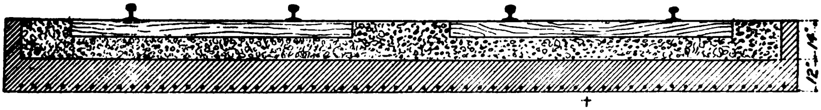


Fig..141.—Railroad Bridge of 10 ft. span, Reinforced Slab Construction.

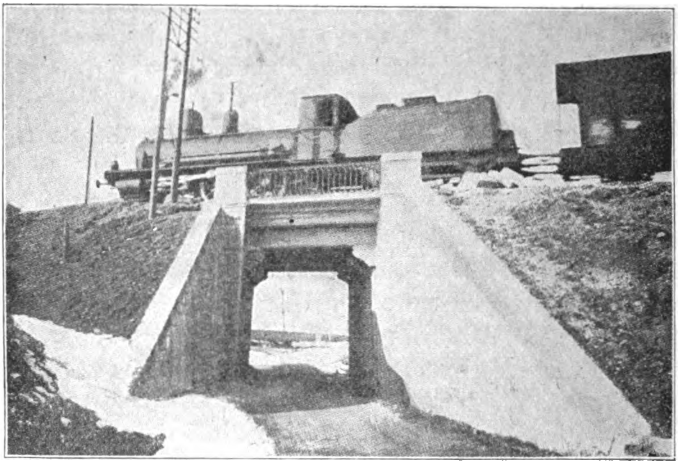


Fig. 142.—Reinforced Concrete Girder Railroad Bridge.

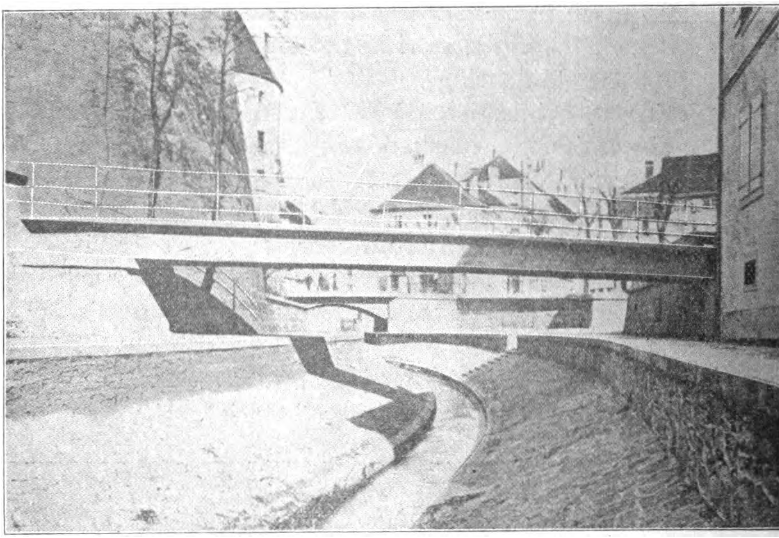


Fig. 143.—Girder Bridge of 50 ft. span.

Simplon R. R. Greater spans than 10 feet for railroad bridges should be of girder and slab construction.

Fig. 142 shows the first viaduct of this kind, built at Creux du Mas, Switzerland. It consists of 10x12 inch beams, six feet apart, spanning 21 feet 4 inches, on a skew of 24 degrees. Tests made by the Railroad Co. before acceptance of this structure showed deflections of 0.13 inch, when the heaviest locomotive passed at a speed of 40 miles an hour. Tests made two years later showed that this deflection had diminished 1-3, proving, without doubt, that the adhesion of plain round steel rods to concrete is sufficient and not weakened by vibrations caused by passing trains and that a reinforced concrete bridge becomes stronger with age.

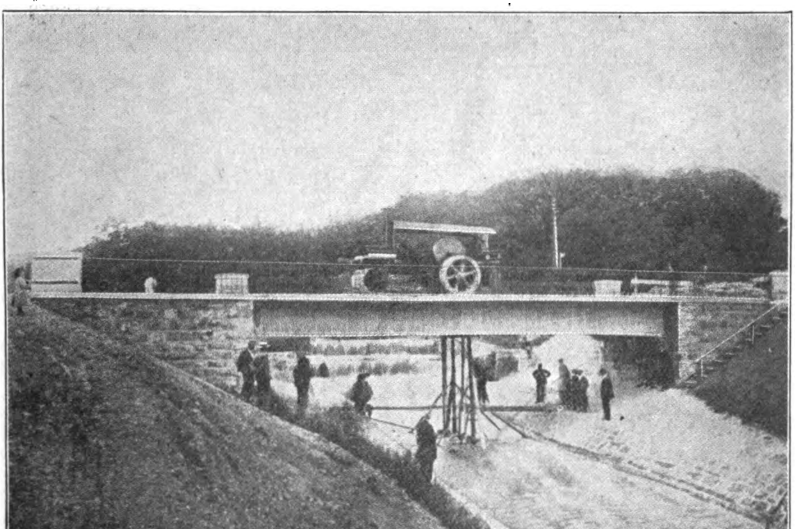


Fig. 144.—Girder Bridge tested by a 20 ton Steam Roller. Maximum deflection 1-12,000 of the span.

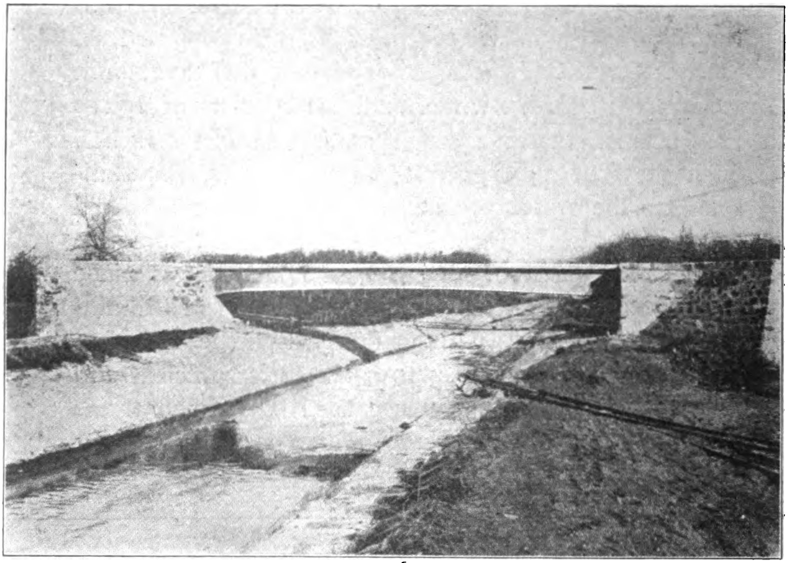


Fig. 145.—Reinforced Concrete Girder Bridge of 52 ft. span. Rubblestone abutments, girders slightly arched.

A very economical type of highway bridges is shown by Figs. 143 to 145. Reinforced concrete girders, six to fourteen feet apart, support the roadway, consisting of a concrete slab, stiffened by girders, while the side-walks are built in cantilever, as shown in Fig. 146. The roadway can be formed of macadam or

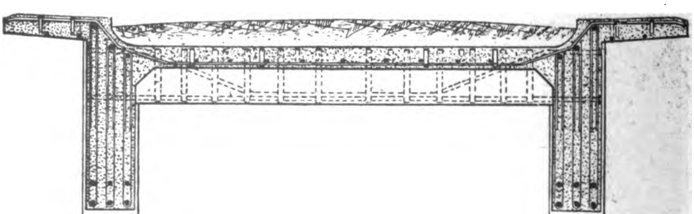


Fig. 146.—Section through Reinforced Girder Bridge.

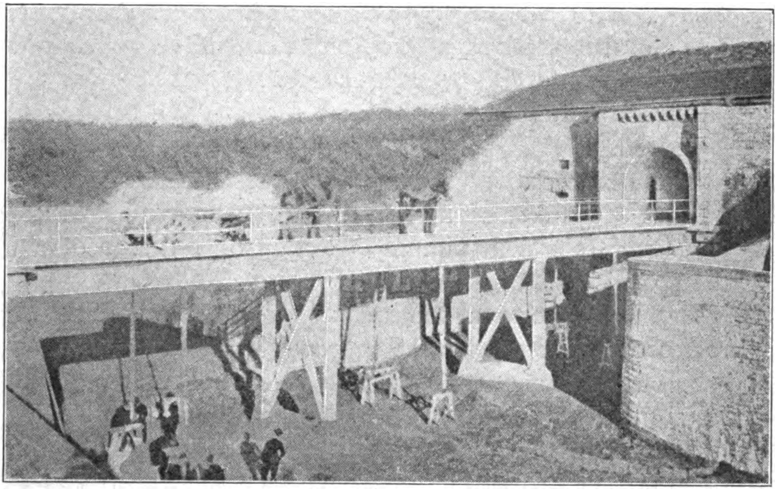


Fig. 147.—Bridge at Fort De Bron, designed to carry a load of extremely heavy pieces of artillery for the fort.

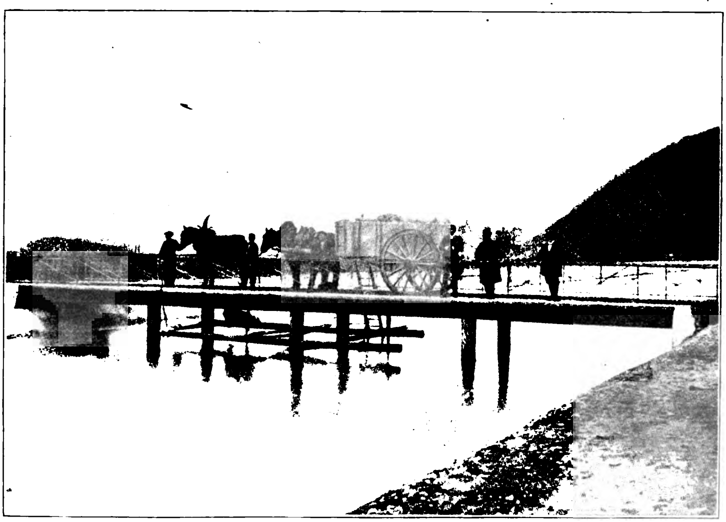


Fig. 148.—Continuous Girder, Bridge on Concrete Pier Foundation.

of a layer of asphalt or of a two inch cement finish. The abutments for such bridges can be built of rubble stone or reinforced concrete or concrete sheet piles where the ground is very bad and a low priced bridg is desired.

These bridges are very rigid and the tests on above bridges of 50 feet span showed under a moving load of twenty tons a maximum deflection of 1-12,000 of the span.

Fig. 147 shows a continuous girder bridge with reinforced concrete trestle supports, while Fig. 148 shows a continuous girder bridge on concrete piers of small diameters, which piers reduce as little as possible the profile of the river. This class of bridges can be built with advantage for unsupported spans up to 70

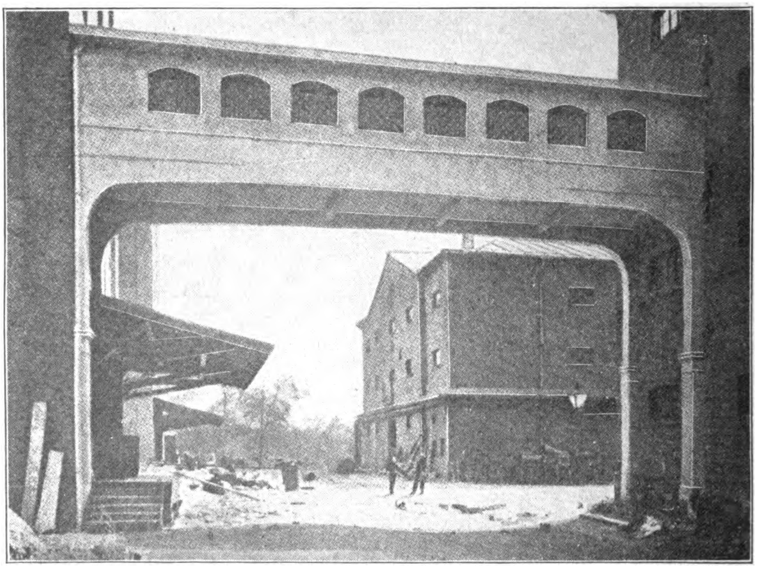


Fig. 149.—Tubular Bridge connecting two Refrigerators.

feet; for larger spans they become more expensive than arched bridges. Fig. 149 shows a tubular bridge connecting two refrigerating plants of a brewery.

Arched bridges of reinforced concrete can be built up to 500 feet span. The great success of armored concrete in building arched bridges is based on the adoption of arched ribs similar to steel bridges and by supporting the roadway by columns resting on the arched ribs. This reduces the dead weight and the cost of the bridge. Other systems of reinforced concrete construction usually adopt an arched floor 6 inches to 3 feet thick with spandrel walls, filling in the space between arches and the road grade with earth, and paving the surface. This, of course, gives a much

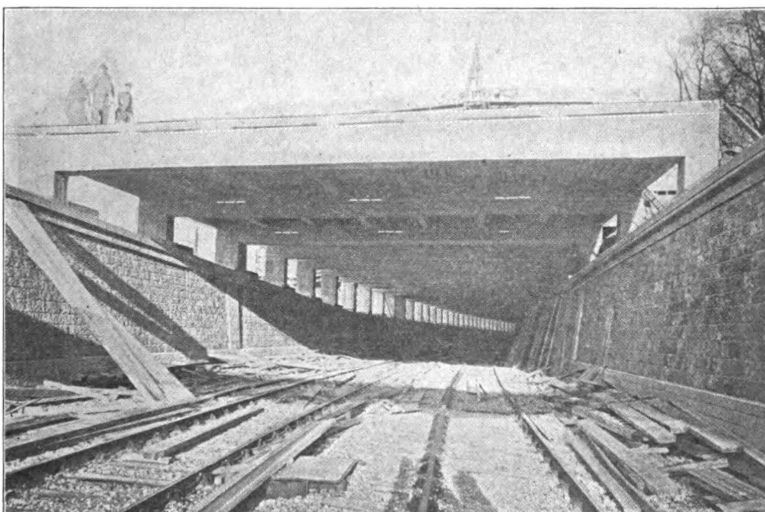


Fig. 150.—Covering of a Subway of the Metropolitan Electric Railway, Paris, France. Girders, 52 ft. span; live load, 200 pounds per square foot.

heavier bridge, similar to a solid stone bridge, and considerably increases the weight on the foundations and arched floors. Reinforced concrete should not imitate stone, but should create its own particular style of architecture, which is light and graceful; in case of arched bridges this approaches more the design of steel bridges than stone bridges. Fig. 151 shows a splendid example of an arched concrete bridge. It was built in 1898, at Chaterellault, France, and is 26 feet wide by 450 feet long. The central arch has a span of 164 feet and the side arches of 135 feet. All arches have a rise of 1-10 of the span. There are 4 concrete ribs 6 feet 3 inches apart, being only 20 inches deep in the centre, which are connected throughout by a five inch concrete floor for wind bracing. The road bed consists of a concrete floor 5 inches thick at the curb and 10 inches thick at the centre, which is covered by a coat of asphalt and supported by girders 6 feet 3 inches apart corresponding to the arches below, which girders are carried by 8 inch square colums, resting on the ribs. The piers are built of a shell of concrete 4 inches to 12 inches thick, connected by partitions in the same vertical plan as the arched ribs and the whole is filled with a low grade concrete. The piers rest on the rock which was found at a small depth below the river bottom. The side-walks, which are 5 feet wide, overhang for a distance of 3 feet 5 inches. The bridge was built in the short time of 3 months, and cost slightly less than $35,000.

The tests by a Commission of Engineers and representatives of the government and the municipality of Chatellerault were made in the following manner:

First, each span was loaded over its total length, then on each half, then on its central part, with moist sand

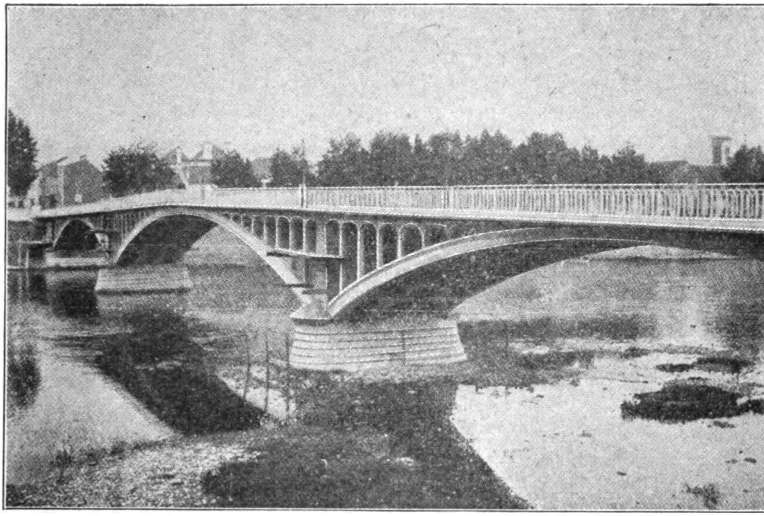


Fig. 151.—Bridge at Chatellerault, 26 feet by 450 feet long, central arch of ~~450~~ 164 ft. span, side arches 135 ft. span, rise 1-10 of the span.

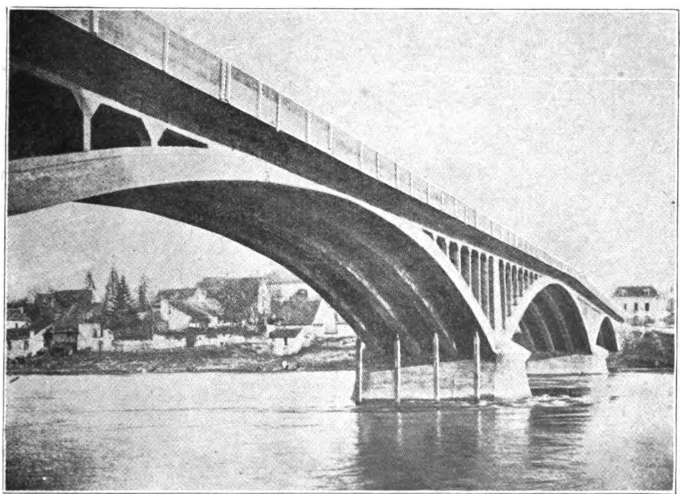


Fig. 152.—Bridge at Chatellerault

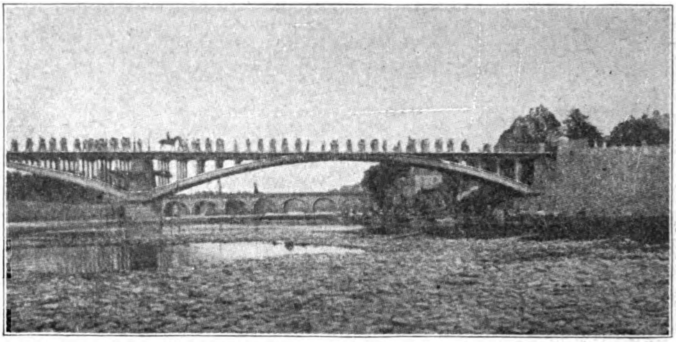


Fig. 153.—Bridge at Chatellerault with soldiers passing over.

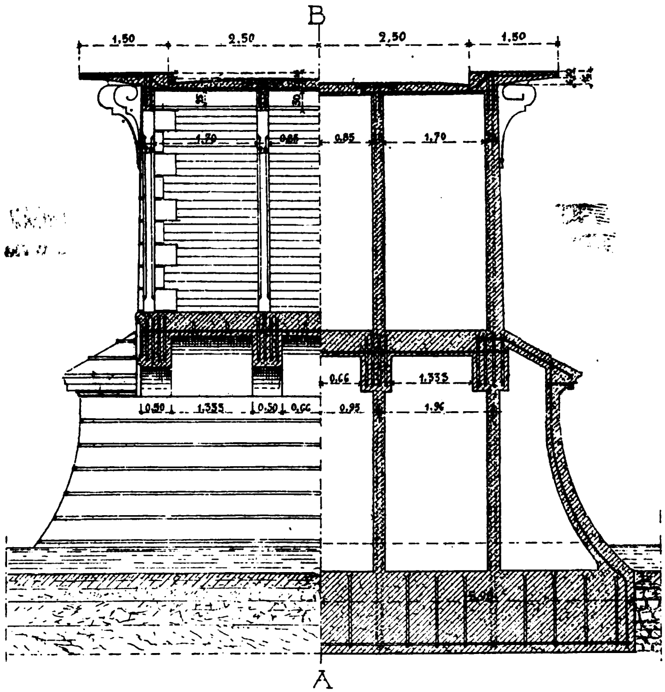


Fig. 154.—Section through Pier of Chatellerault Bridge.

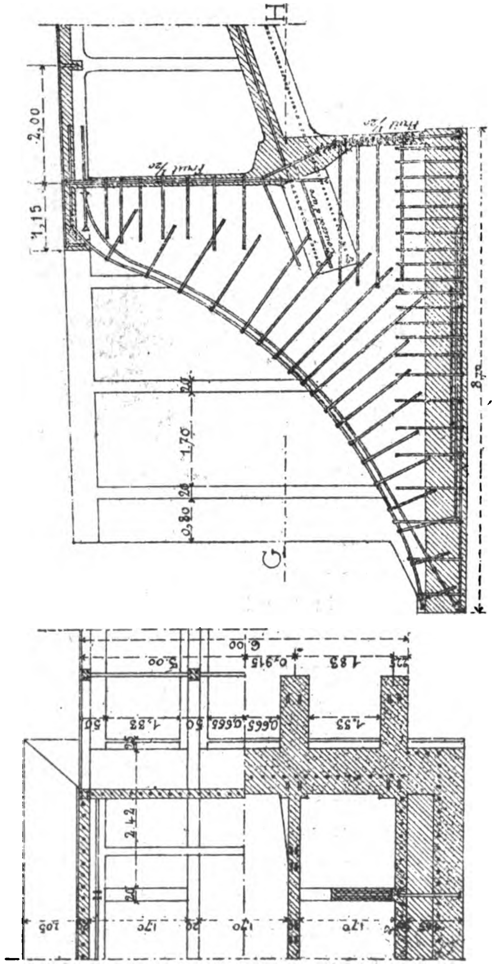


Fig. 155.—Section through Abutment of Bridge at Chatellerault. Base plate 30 ft. long. Heavy ribs, in the same plan as the arches, transmit thrust to the ground. Reinforced concrete curtain walls connect the ribs and take up the earth pressure.

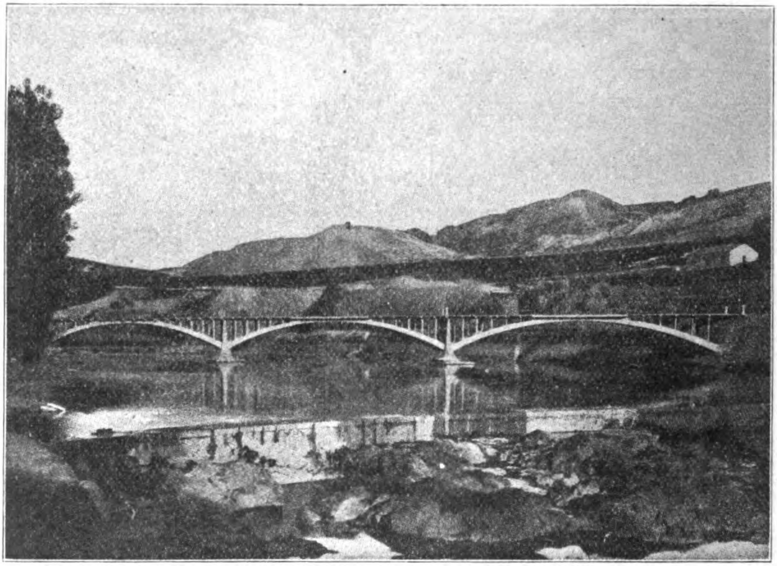


Fig. 156.—Highway and Electric Railway Bridge at Bilbao, Spain. Consists of five arches of 120 ft. span, of which only three are visible in the illustration. This bridge has a much lighter appearance than a steel bridge.

at the rate of 165 pounds per square foot on the roadway and 123 pounds on the side-walks.

The official report of the test is as follows:

The maximums of deflections weree 1-4 inch for the arch at the left bank, 7-32 inch for the arch at the right bank, and 13-32 inch for the central arch, that is 1-7300 and 1-5000 of the spans, respectively. The specifications allow deflections of 9-16 inch for the 135-foot span and 2 inches for the 164-foot span. After removing the loads no permanent deflection could be detected.

The moving test load consisted of:

First. One 16-ton steam roller.

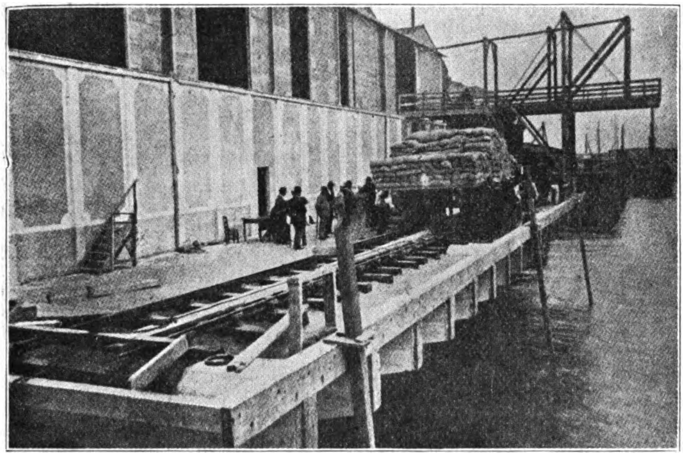


Fig. 157.—Cantilevers of 27 feet carrying a Railroad track.

Second. Two four-wheeled wagons weighing 16 tons in all.

Third. Six two-wheeled wagons weighing 8 tons in all; making a total of forty tons moving simultaneously over the bridge, while the sidewalks were loaded to 80 pounds per square foot. Strips of wood were strewn over the roadway in order to produce shocks when the steam roller passed over them. The maximum deflection under these loads was less than 1-9000 of the span.

Furthermore, a troop of 250 infantrymen crossed the bridge, first in ordinary marching order, then in double quick time.

The most remarkable feature shown by these tests was that a load on one arch caused a perceptible rise in the two adjacent arches, an evident proof that ferro-concrete structures are monoliths.

Fig. 158.—Arched Bridge of 60 ft. span. Ribs support by means of spandrel columns, the reinforced concrete roadway; railings consist of reinforced concrete posts and arches.

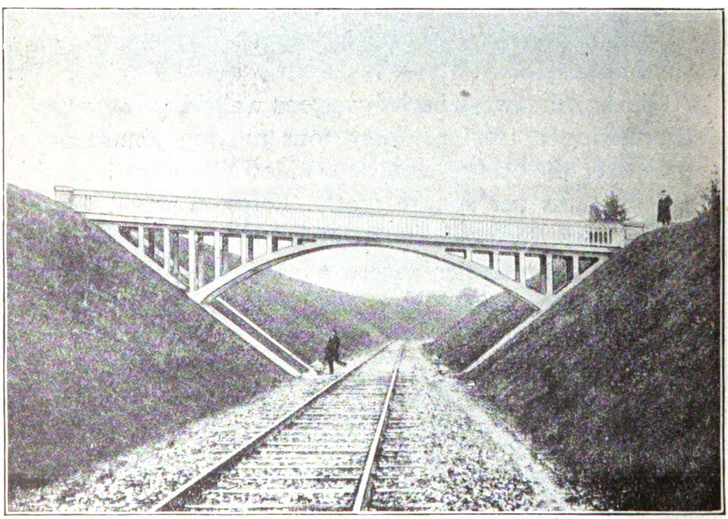


Fig. 159.—Arched Bridge of 50 ft. span.

Figs. 158 and 159 show smaller arched bridges designed on similar lines with the difference that the arched ribs are not connected by a concrete floor for wind bracing, but only by 8x8 inch ties. In this case the wind stresses must, of course, be taken care of by the concrete floor of the roadway and transmitted from the arched ribs by the spandrel columns to this roadway. This makes a very neat and low priced design, and bridges of this type will be found to be less expensive than steel bridges with wooden floors.

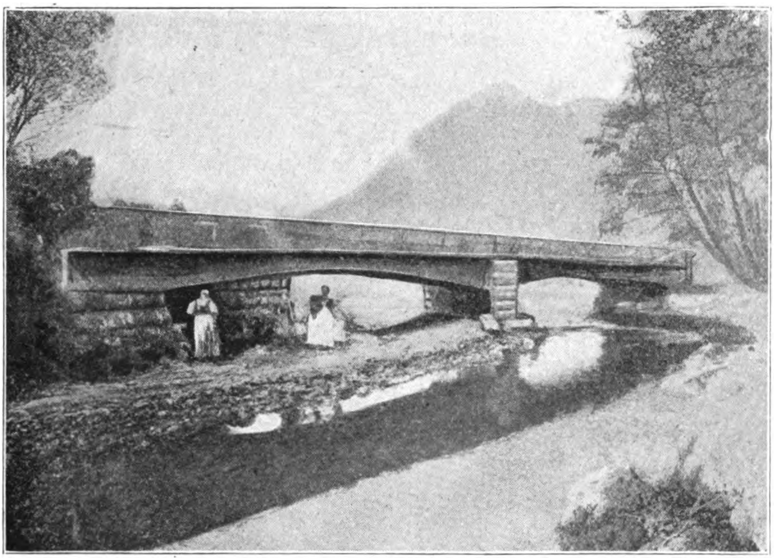


Fig. 160.—Arched Bridge carrying a canal.

Figs. 160 to 167 show arched bridges where the ribs are solid from the roadway down. This is in imitation of arched stone bridges, the difference being that these bridges consist of ribs from 6 to 10 feet apart with a concrete floor for the roadway and therefore of

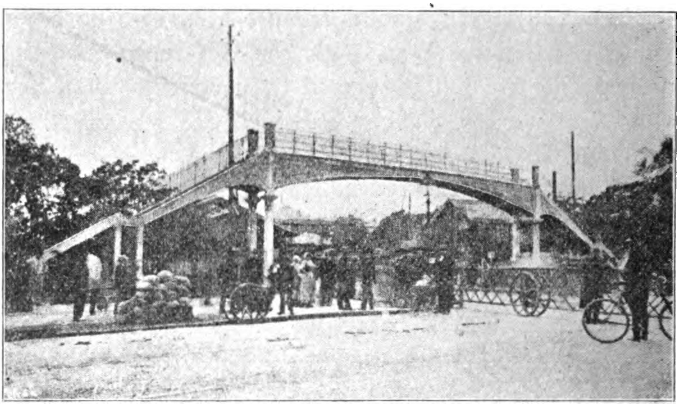


Fig. 161.—Foot Bridge over Railroad, 60 ft. span.

hollow construction and much lighter than stone bridges, while they resemble them in appearance. Fig. 160 shows a concrete bridge carrying a conduit; consists of two arches each of 42 feet span, and a cantilever sidewalk. . Figs. 161 and 162 show veary neat designs for foot bridges over railroad tracks. The cost of these bridges was about 25 per cent. less than of structural steel. Fig. 168 shows an arched bridg designed on the Monier system with an arched floor and concrete walls to support the roadway.

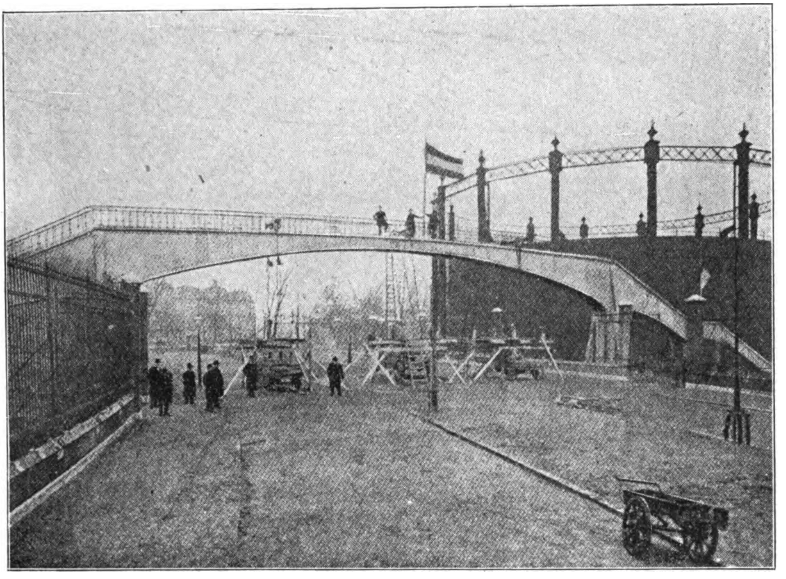


Fig. 162.—Foot Bridge of 100 ft. span.

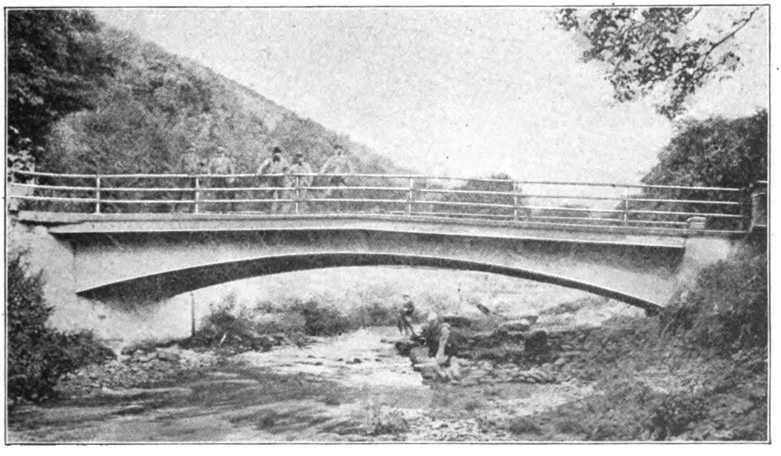


Fig. 163.—Reinforced Arched Highway Bridge of 50 ft. span.

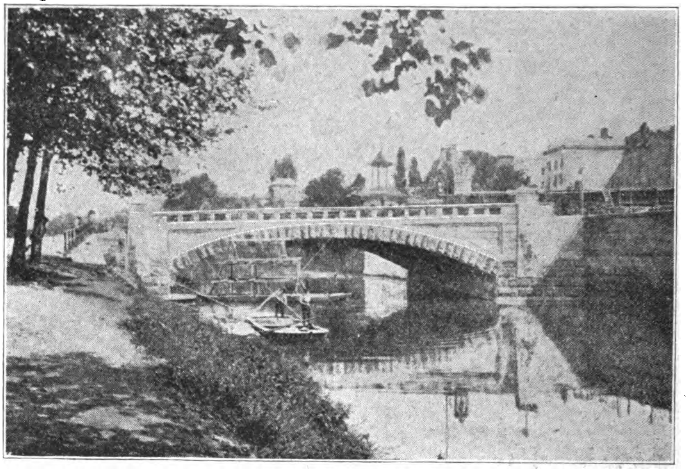


Fig. 164.—Highway Bridge with Stone Lining.

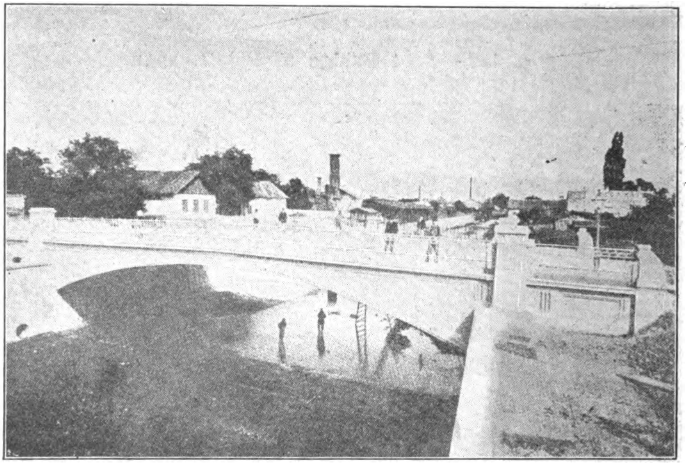


Fig. 165.—Skew Bridge of 72 ft. span.

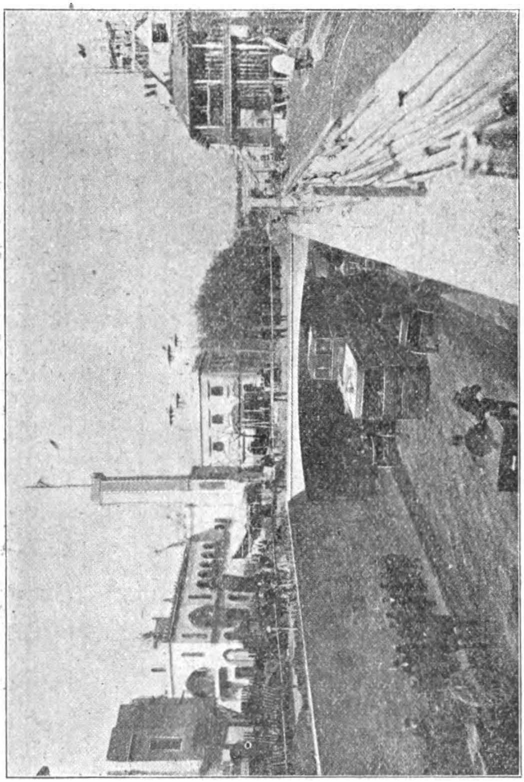


Fig. 166.—Retaining Walls and Arched Bridge, Paris, France. This arch has the least rise of any arch ever constructed, having a rise of one foot and ten inches in 46 feet; that is, 1-26 of the span.

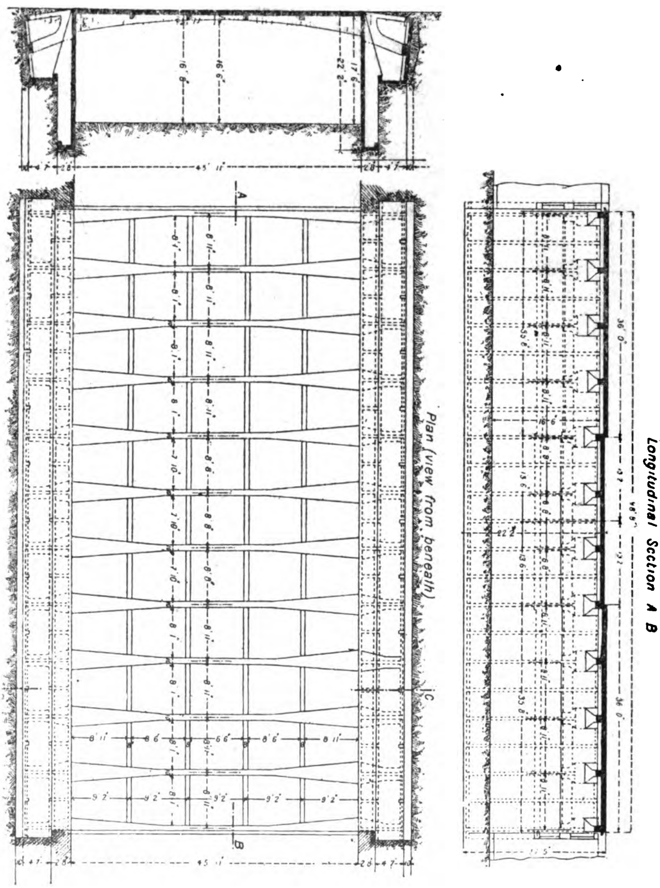


Fig. 167.—Details of Arched Bridge of 46 ft. span.

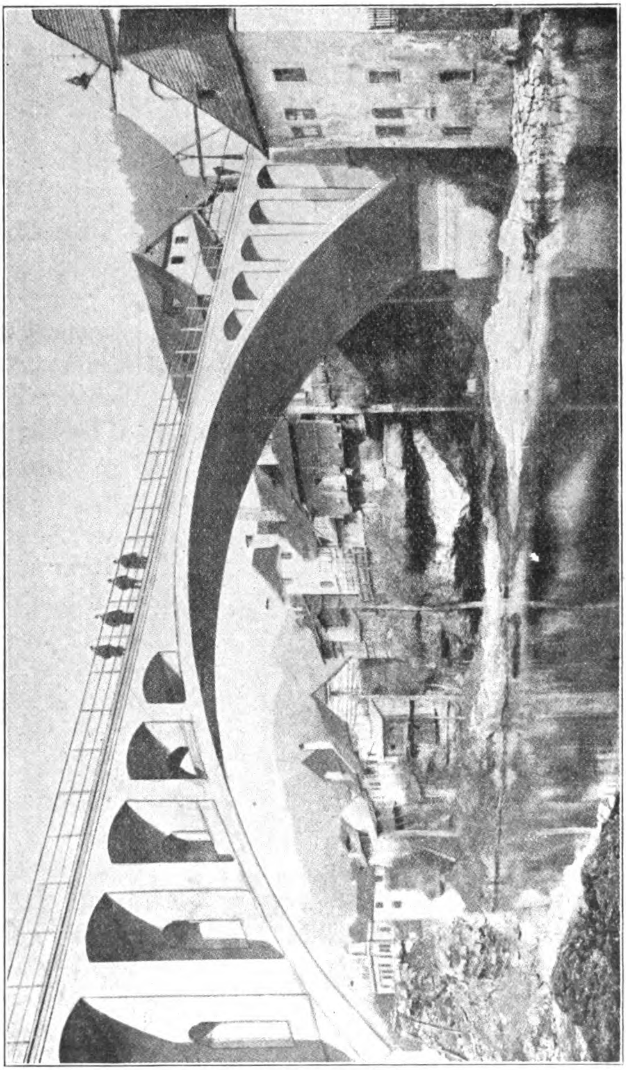


Fig. 168.—Monier Bridge, Ybbs, Austria.

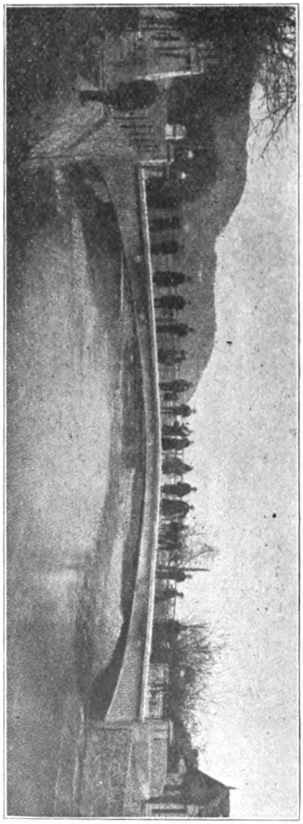


Fig. 169.—Highway Bridge of 80 ft. span.

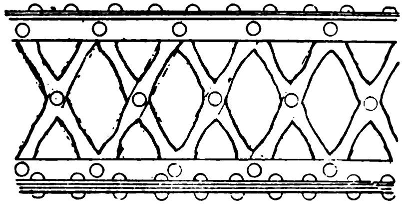
REINFORCING EXISTING STEEL BRIDGES BY CONCRETE.

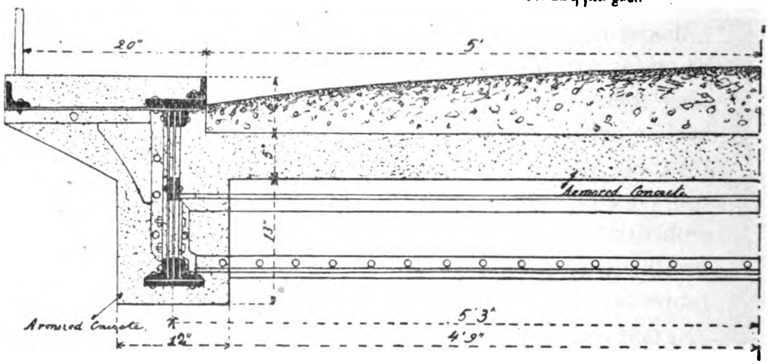
Existing steel bridges which show signs of deterioration or are too weak for the increased loads passing over them, can be reinforced by concrete at often nominal expense. Plate girder bridges can be lined with concrete and additional steel rods added to bottom and top chords. Also cross girders and stringers can be embedded in concrete, and a new concrete floor placed; in this way a new bridge is obtained, which will be more sightly and substantial than the old steel bridge. A good example of such a reinforcement of a bridge is shown in Fig. 170. The lattice work of the main girders and the webs of the cross girders were utterly corroded by sulphurous gases and the sand blast action of locomotives stopping under it.

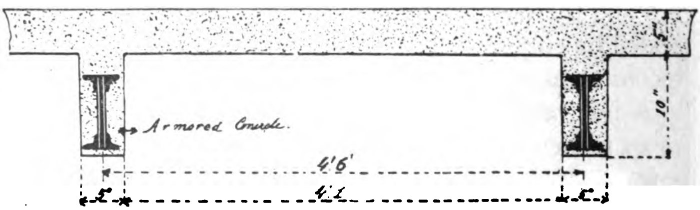
A few yards of concrete, used to embed the main and cross girders and to place a substantial floor, produced a new bridge, which may last indefinitely.

Trussed bridges can also be reinforced in a similar way, embedding bottom and top chords, diagonals and verticals, cross girders and stringers in concrete and adding new steel rods to increase the strength of the various members.

Cement is to-day recognized as the best preserver of iron and steel against rust, and the French railroads now use, exclusively, cement mortar to paint their bridges.







Figs. 170-172.—Reinforcing an old steel bridge with concrete.

The illustrations in these pages were drawn largely from constructions, executed under French systems of reinforced concrete construction, both in this country and abroad.

We are also indebted to the Ferro-Concrete Construction Co., of Cincinnati, for several illustrations.

To-day there are several hundred engineers and contractors engaged in armored concrete construction in Europe and the United States, whose special systems differ only slightly from each other, omitting or inserting more or less important details, from the principles of constructtion heretofore described.

During the last few years, certain so-called patent bars with notches or corrugations, etc., have appeared on the market, for which extraordinary claims have been made in respect to the advantages when used as a reinforcing member. The vendors of these patent bars claim that the adhesion of the concrete to their bars is increased 20 to 50 per cent, over round rods, and, therefore, the strength of a beam or a slab is increased in the same ratio, which is, however, not warranted either in theory or practice. In fact not one in a thousand of the existing structures are built with such patent bars. Experiments on reinforced concrete bridges during the last 10 years prove that the adhesion of concrete to plain steel rods increases with age, and that there is not the least danger of rupturing the bond by shocks; and nearly 20,000 structures where plain steel rods were used, prove that plain steel rods take care of all the stresses they are subjected to. These patent bars are sold at from three to five cents a pound, while plain steel rods to-day cost only one and three-tenths cents a pound. The increase

of adhesion can be secured much easier by simply in creasing the number of plain bars above that given by accepted practice, and we will obtain by this expedient a stronger and less expensive beam, than where the costly patent bars are used. It is true, that on first consideration, these patent bars seem to be a good thing; but the writer is warranted in saying that he prefers to use three times the amount of plain steel rods, in a given member, than to pay three times the price for the patent bars.

GENERAL SPECIFICATIONS FOR REINFORCED CONCRETE CONSTRUCTION.

The work shall be completed in accordance with the general plans, sections and diagrams submitted by the concrete contractor to the architect, engineer or owner. The contractor must prove that the plans are prepared by competent engineers who have had at least three (3) years experience in this line of work with a responsible company. No change shall be made in the plans either in thickness of any member of construction or in size, or position of steel rods, without written permit from the engineer in charge of the reinforced concrete construction.

MATERIALS.

Only first class Portland cement shall be used. Each car load of cement shall be tested and is to conform to the standard required by the United States Government (see the specifications).

SAND—The sand shall be clean and sharp and free from loam or other impurities, and, preferably, a mixture of grains of all sizes from 1-4 inch down to the finest, if such sand can be had at reasonable price.

CRUSHED STONE OR GRAVEL—Shall be free from loam or other impurities, of hard material and no single piece be larger than 3-4 inch for floors, columns, thin walls, or more than 1 inch in footings. The material should contain all sizes from the specified sizes down to and including stone dust; the percentage of stone dust shall not exceed 10 per cent of the crusher run.

CONCRETE—At least one barrel of cement for each cubic yard of concrete shall be used. The proportion

of cement sand, and crushed stone or gravel shall not be less than 1:2:4 for columns or girders, and 1:2 1-2:5 for walls, floors and footings. Whenever the amount of concrete justifies the use of a concrete mixer, machine mixed concrete shall be used. Any kind of batch mixer shall be allowed. The ingredients shall be placed in the machine in a dry state, and be thoroughly mixed, after which clean water shall be added and the mixing continued until a uniform mixture is obtained. Where the mixing is done by hand, the cement shall be thoroughly mixed dry on a tight platform of planks or sheet iron, then the previously wetted stone shall be spread on the mixture of sand and cement, clean water added, and the whole turned over two or three times until a perfectly uniform mixture is obtained.

The mixing shall be done as rapidly as possible and the concrete deposited in the work without delay. The concrete shall be mixed moderately wet, so that tamping is required to bring water to the surface. At no time shall concrete be as wet as to allow the stones to sink in the wheel barrows, and the cement and sand and water to rise to the surface. The concrete may be fairly wet for walls, which have little to carry, so that churning of the concrete only is required to get rid of the air drawn in by pouring.

The materials shall be measured loose, but in a uniform manner, so that the proportions can be easily controlled by workmen and inspectors. The concrete shall be deposited in a layer of a few inches, never exceeding six, and rolled or rammed till the water appears at the surface. Where a complete section of the work joins a section just being deposited, extra care shall be taken that the surfaces are well picked out,

and washed clean with water, and well grouted, in order to make a proper bond between the sections. This applies especially to the joints of columns with girders, girders with floors, floors with walls, etc.

FORMS—The forms shall consist of 1 to2 inch boards of uniform thickness joined carefully together, straight and true to line, so that the irregularities in the exposed concrete surfaces shall not be greater than 1-4 inch. The forms have to be well braced and supported, so that there be no undue deflection, when the concrete is deposited.

The forms for girders shall not be removed before three weeks to four weeks, for floors not before one to two weeks, according to the temperature. The sides of columns and walls may be removed in one to two days; the surface has, however, to be sprinkled to prevent checking on account of too rapid hardening of the layers. This sprinkling has to be done during warm and dry weather and continued for several days on all newly built concrete, especially floors.

CONCRETING IN COLD WEATHER—Concreting above 30 degrees Fahrenheit may be carried on without heating the materials. In temperatures above 26 and below 30 degrees F., the cement, sand and water shall be heated, and the concrete covered immediately by cloth and a thick layer of sand. No concreting of important parts of the work shall be carried on below 26 degrees F. The weather reports must be consulted daily and if a cold spell is predicted the next 12 hours, work must be stopped.

IRON—Shall have an ultimate tensile strength of not less than 50,000 lbs. per square inch; and the elastic limit shall not be less than 25,000 lbs. It must bend

cold 180 degrees around a rod whose diameter is equal to the thickness of the piece tested, without any sign of failure.

STEEL—Shall have an ultimate tensile strength of at least 60,000 lbs. per square inch, and an elastic limit of not less than half the ultimate tensile strength. It must bend cold 180 degrees around a curve, whose diameter is equal to the thickness of the piece tested, without crack or flaw on outside of bend. All iron or steel used must be free from dirt or other impurities, but may have a slight coat of rust, which coat facilitates the forming of a hard coat of ferro calcite, and increases the adhesion to the concrete.

TESTS—Five per cent. of all girders shall be tested to at least 1 1-2 times the specified loads and the deflection shall not be greater than 1-800 of the span. No crack or other indication of weakness shall be permissible. Any girder not passing these tests shall be rebuilt in armored concrete or replaced by steel construction at the discretion of the architect.

SPECIFICATIONS FOR PORTLAND CEMENT. U. S. ARMY CORPS OF ENGINEERS.

The cement shall be an American Portland, dry and free from lumps. By a Portland cement is meant the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances; the calcined product should contain at least 1.7 times as much lime, by weight, as of the materials which give the lime its hydraulic properties; it should be finely pulverized after said calcination, and thereafter addition or substitution not to exceed 2 per cent. of the calcined products should be allowed, and only for the purpose of regulating certain properties of technical importance.

The cement shall be put up in strong, sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

No cement shall be used except established brands of high grade Portland cement which have beeen made by the same mill and in successful use under climatic conditions similar to those of the proposed work for at least three years.

The average weight per barrel shall not be less than 375 pounds net. Four sacks shall contain one barrel of cement. If the weight, as determined by test weighings, is found to be below 375 pounds per barrel, the cement may be rejected, or, at the option of the engineer of officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

Tests may be made of the fineness, specific gravity, soundness, time of setting and tensile strength of the cement.

FINENESS—Ninety-two per cent. of the cement must pass through a sieve of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

SPECIFIC GRAVITY—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 3.10 and 3.25.

SOUNDNESS—To test the soundness of the cement, at least two pats of neat cement mixed for five minutes with 20 per cent. of water by weight shall be made on glass, each pat about three inches in diameter and one-half inch thick at the center, tapering thence to a thin edge. The pats are to be kept under a wet cloth until finally set, when one is to be placed in fresh water for twenty-eight days. The second pat will be placed in water which will be raised to the boiling point for six hours, then allowed to cool. Neither should show distortion or cracks. The boiling test may or may not reject at the option of the engineer or officer in charge.

TIME OF SETTING—The cement shall not acquire its initial set in less than forty-five minutes and must have acquired its final set in ten hours.

(The following paragraph will be substituted for the above in case a quick-setting cement is desired:

The cement shall not acquire its initial set in less than twenty nor more than thirty minutes, and must have acquired its final set in not less than forty-five minutes, nor in more than two and one-half hours.)

The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one-twenty-fourth inch in diameter loaded to weigh one pound.

TENSILE STRENGTH—Briquettes made of neat cement, after being kept in air for twenty-four hours under a wet cloth, and the balance of the time in water, shall develop tensile strength per square inch as follows:

After seven days, 450 pounds; after twenty-eight days, 540 pounds.

Briquettes made of 1 part cement and 3 parts standard sand, by weight, shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after tenty-eight days, 220 pounds.

(In case quick-setting cement is desired, the following tensile strength shall be substituted for the above:

Neat briquettes: After seven days, 400 pounds; after twenty-eight days, 480 pounds.

Briquettes of 1 part cement to 3 parts standard sand: After seven days, 120 pounds; after twenty-eight days, 180 pounds.)

The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight day tests over the seven-day tests, shall be rejected.

When making briquettes neat cement will be mixed with 20 per cent. of water by weight, and sand and cement with 12 1-2 per cent. of water by weight. After being thoroughly mixed for five minutes, the cement or mortar will be placed in the briquette mold in four equal layers, and each layer rammed and compressed by thirty blows of a soft brass or copper rammer three-quarters of an inch in diameter (or seven-tenths of an inch square, with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When ramming has been completed, the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deem it to be to

the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner herein specified. All expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.